

CHEMICAL LECTURES,

Publickly Read at LONDON,

In the Years 1731, and 1732;

And at SCARBOROUGH, in 1733;

For the IMPROVEMENT of

A R T S, T R A D E S,

A N D

NATURAL PHILOSOPHY.

By *PETER SHAW*, M. D. F. R. S.

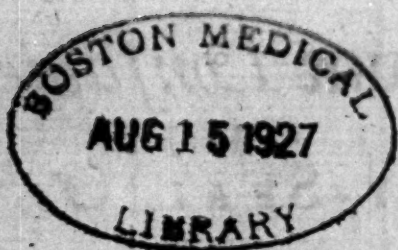
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TO THE

Right Honourable the

Lord Viscount *Lonsdale*,

Lord PRIVY-SEAL, &c.

MY LORD,

AS your Lordship was pleased to honour these Lectures with your Notice in Manuscript, I take the Liberty of laying them before you in Print ; being desirous the Publick should know, that their Design was approved of by so unexceptionable a Judge.

iv DEDICATION.

For, besides your uncommon Skill in Civil Policy, the Laws, and all the Branches of Publick Business; you have, like the Illustrious Lord *Bacon*, a Talent for the Improvement of Arts, and a Pleasure, and Sagacity, in pursuing natural Enquiries.

Were I not, therefore, sensible, my Lord, that your Candour is as extensive as your Learning, I should be cautious of thus submitting these slender Enquiries to your View; as they are neither conducted in a Manner suitable to your correct and exquisite Taste; nor pursued to such a Length, as your great Knowledge in Philosophical Matters may justly require.

But this gives me farther Encouragement, that I do not know a more useful

DEDICATION.

v

ful Subject, than the present, to a Trading Nation; nor a Person better qualified than your Lordship, to perceive its Tendency, and direct its Improvement.

I am

MY LORD,

YOUR LORDSHIP'S

Scarborough,
July 15. 1733.

*Most obliged, and devoted humble
Servant,*

PETER SHAW.

ADVERTISEMENT.

THE following Lectures had the Honour to be read before a noble Audience, who candidly overlooked their Failings, and requested their Publication.

As the Design is of large Extent, little more than a Sample of the whole could at present be given; the farther Improvement of it being left to others.

The Experiments here employed, tho' many of them new, are generally simple; or performable with little Cost, and Apparatus: But if a few particular Instruments, and Trials, hereafter intimated, were to be made, and properly used, much greater Discoveries might be reasonably expected.

A

GLOSSARY:

O R

Explanation of the TECHNICAL
TERMS in this Work.

Acid. By *Acids* are meant all those Things that taste sour; as Vinegar, Tartar, Juice of Crabs, Lemons, &c. Spirit of Nitre, Spirit of Salt, &c. and which, when mixed with a due Proportion of an *Alkali*, constitute a neutral Body, wherein neither *Acid* nor *Alkali* prevails; whence it alters not the Colour of Syrup of Violets. See *Alkali and Neutrals*.

Adits. See *Burrows*.

Alcohol. Is pure and perfect Spirit of Wine, without the least Particle of Water, or Phlegm.

Alkali. Is a Word of extensive Signification, and chemically denotes a large Tribe of Bodies. For all Bodies may be chemically considered under three Tribes; or as being either *Alkalies*, *Acids*, or *Neutrals*. *Alkalies* have this essential Property, that when mixed, or united, with *Acids*, they constitute *Neutrals*. But a more common Mark of an *Alkali* is, that it turns Syrup of Violets green, as an *Acid* turns it red; whilst the Admixture of a *Neutral* Body does

not alter the Colour of that Syrup. Thus Pot-Ash, Salt of Tartar, and all fixed vegetable Salts ; as likewise all volatile animal Salts and Spirits, are artificial *Alkalies* ; as Chalk, the testaceous Bodies, &c. are natural *Alkalies*. And thus, in the vegetable Kingdom, Onions, Leeks, Garlick, Mustard, &c. are *Alkaline* ; as Sorrel, Wood-Sorrel, the Juice of Lemons, Oranges, Verjuice, &c. are *Acid*. Their Difference also is manifest from the Taste, when the Habit of thus distinguishing them is acquired. See *Acids and Neutrals*.

Amalgamation. Is the Dissolution, or Mixture of any Metal with Quicksilver : But Iron, of all the Metals, will not amalgamate, or unite therewith.

Assaying. Is the Art of discovering how much pure Metal is contained in any Ore, or Coin, assigned. Hence *to make an Essay*, is to produce a Lump, or Grain, of pure Metal, from any small Quantity of Ore, or Coin.

Axioms. By *Axioms* are meant a Kind of Corollaries, Consequences, or Results, of certain Experiments, Facts, Observations, or particular Doctrines ; so as to recapitulate a certain useful Truth, contained in the preceding Part of the Work, and set it in a clearer Light, with regard to Theory, or Speculation ; As Canons, or Rules, regard Experience or Practice. See *Canons*

Balneum Mariæ. Of Water-Heat, is no more than a Vessel of Water, set in a Furnace, or over the Fire, with another Vessel put into the Water ; which latter Vessel contains the Matter, or Subject, of the Operation.

Buddling Dishes. Are shallow Dishes, like the Basins of a Pair of Scales, for the washing of Ores by the Hand.

Burrows.

A GLOSSARY.

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Burrows. In Mining, are the Passages leading into a Mine, and cut thro' the Sides of a Hill, or Mountain, so large that the Workmen may conveniently wheel out the Ore in Barrows, or carry it along in Baskets.

Calcination. Is the burning of a Body in an open Fire, in order to discharge its more volatile Parts, or reduce it to Powder.

Canons. Are Rules of Practice, or Directions, for producing Effects, or performing Operations; and have the same Regard to Practice, as Axioms have to Theory. *See* Axioms.

Caput Mortuum. Is that Part of the Matter, which remains behind after Distillation, or Sublimation.

Cementation. Is the close burning of a hard or metalline Body, with certain opening Powders, strew'd betwixt its grosser Parts; so as to soften, tinge, or impregnate them, with the Fumes of such Powders; or it is the Introduction of any Mineral, or Metallic Fumes into the solid Plates of a Metal, by Means of a proper Heat, applied to a close Vessel, or double Crucible, wherein the Plates are laid, with the pulverized Matter strew'd between them.

Clarification. *See* Depuration.

Concentrating. Is bringing the required Parts of a Subject closer together; as Salt-Water is concentrated by evaporating the aqueous Humidity; and Wine by freezing out, or separating its Water, in the Form of Ice.

Copelling, or Cupelling. Is putting metallic Matters upon a cover'd Vessel of Bone-Ashes in a naked Fire, to try what Gold or Silver they will afford.

Crystallization. Is the Operation, whereby Salts dissolved in Water shoot into Glebes, of particular

ticular Figures, according to the Nature of each Salt.

Decantation. Is the pouring off a clearer Liquor from a grosser Sediment, after standing.

Deflagration. Is setting explosive Matters on Fire in a Crucible, or other Vessel, and suffering them to burn out; as when Nitre, or Tartar, are thrown into a red-hot Crucible, or to any melted Matter, whilst it continues in the Fire.

Depuration. Is the making of any Matter pure, or freeing it from the Dross, Dirt, or other heterogeneous Parts, wherewith it may happen to be mixed: So Honey is depurated, or clarified, by heating it, and taking off the Scum that rises to the Top.

Digestion. Is suffering solid and liquid, or grosser and finer Matters, to stand together in a gentle Heat for some Time, that the Liquor may extract the Virtues of the solid Ingredients; or the whole become more subtile and uniform.

Distillation. Is the raising of Liquids into Vapour by Heat; and condensing that Vapour into a Liquid again.

Elæosaccharum. Is an intimate Mixture of any essential Oil, with Sugar; by grinding them together in a Mortar.

Elements. See Principles.

Elixation. Is the washing a Matter with Water, in order to get out what will dissolve therein.

Empyreuma. Is a nauseous Taste, or Odour, proceeding from the Subject being scorched, or over-heated, in the Operation; as when Milk is burnt to, as they call it.

Essential, or Chemical Oils. Are the native Oils of Vegetables, drawn from them by Distillation with Water.

Evaporation.

Evaporation. Is the setting a Liquor in a gentle Heat, to discharge its superfluous Humidity, or obtain its dry Remainder.

Faints. Are the Liquor that runs from the Still, upon distilling any inflammable Spirit, after all the Proof-Spirit is come over. See Proof.

Filtration. Is suffering any Liquor to pass thro' Cap-Paper, or rather a peculiar Kind of filtering Paper, into a clean Vessel, or Glass; the Paper being cut conically for the Purpose, and put into a Glass Funnel, or laid upon a Stone Colander, or Strainer.

Form. Is the particular Act, or Law of Nature, whereby a Thing is produced.

Flux. Is any Matter added to an Ore, or metallic Matter, in order to make it melt, or run the easier, and yield a greater Quantity, or a purer Metal.

Fulmination. Is the same as *Deflagration*, which see.

Fusing. Is the same as Melting, being a Term generally applied to the melting of Metals, and metallic Matters, with a strong Heat.

Insolation. Is suffering Matters to stand and digest in the Heat of the Sun, instead of using the Heat of a Furnace.

Lac, or Laque. Is a Kind of Extract, or thick Body of Colour, prepared chiefly from vegetable Subjects, for Painters Use. Of these *Laques* there are several Sorts; but in a more particular Sense, it signifies the *Red Laque* obtained by boiling *Stick-Lac* in Water.

Lavaderos. In Mining, are the Houses, or large Troughs, where the Ore is washed.

Limation. Is the filing of a Metal, or metallic Substance, so as to reduce it into small Parts, called the Filings of that Metal.

Lixivium.

Lixivium. Is the same Thing as Lee, or a Solution of Salts, by boiling any saline Matter in Water.

Load. In Mining, is the same as Ore.

Lotion. Is the washing of a Body in Water, to get out its Salt, or whatever else will dissolve in Water.

Low-Wines. Are a weak Spirit, or the first Runnings of the Still, in distilling Brandies or Spirits, from Wash or Wines, and mixed along with the second Running, or more watry Part.

Menstruum. Is any Body applied to another, so as to dissolve it, and intimately mix its Parts with the Parts of the other : in which Respect the former may be called the *Solvent*, and the latter the *Solvend*.

Mercury. Is another Name for *Quicksilver*.

Metallurgy. Includes the whole Art of working Metals from the Ore to saleable Metal.

Muffle. Is an arched earthen Instrument made to cover a Test, in Cupelling, so as that the Coals, or Ashes of the Fire, may not fall in upon the Subject. See Cupelling.

Must. Is the unfermented Juice of the Grape ; or any other liquid fermentable Substance, before it enters the Act of Fermentation. See Stum,

Neutrals, or Neutral Bodies. Are such Bodies as manifest no Signs of either *Alkali*, or *Acid*, upon any of the Trials known, and allowed to discover them ; as particularly not by the Taste, or the Admixture of Syrup of Violets, &c. See Acid and Alkali.

Per Deliquium. Is the running of dissolvable Things into Liquor, by barely exposing them to the open Air, or to the moist Air of a Cellar.

Pblegm. Is the same as Water, or aqueous Liquor.

Precipitation. Is the depositing of a Sediment; either by a Liquor standing at Rest, or when any Addition is used for the Purpose.

Principles. Are the different simple Matters, whereof a Body is composed.

Proof. In Spirits is meant of a certain Trial, or Way of examining their Strength, by the Bubbles that arise on their Surface upon shaking them in a Phial.

Quartation. Is the Separating of Gold from Silver, by Means of *Aqua Fortis* or *Aqua-Regia*.

Quintessence Is the Mixture of an essential Oil with *Alcohol*.

Rectification. Is purifying a Subject, by repeating the Operations; as Brandy is purified, or separated, from its Phlegm, by repeated Distillation.

Reduction. Is the *reducing*, or recovering a Metal from its *Calx*, or *Asbes*; and may likewise be applied, when any Body destroyed, as to its natural Form, or Appearance, is made to assume that Form again.

Refrigeratory. Is a Vessel of cold Water, thro' which a winding metalline Pipe takes its Course, from the Hot Still, so as to bring off the Liquor cool, by Distillation.

Regulus. Is an impure, or imperfect metallic Substance, that falls to the Bottom of the Crucible in the melting of Ores, or impure metallic Substances.

Scoria. See Slag

Separating-Glass. Is a bellied Glass, open at top, and ending in a hollow Stem below; so that a Mixture of Oil and Water being put therein, and suffered to rest till they separate, the Water may be poured off from the Oil.

Slag.

Slag. Is the Dross, Crust, or *Scoria*, found at the Top of a melted Metal, or metallic Matter; being often in the Form of a vitrified Mass, or Glassy Substance, and proceeding from the Flux employed, and united with some stony recrementitious Matter contained in the Ore. But when a large Proportion of a saline Flux is used, the Slag will relent, or even dissolve in the Air.

Solvent. See Menstruum.

Stum. Is *Must*, clarified by standing and racking, then put up into matched Casks, that is, Casks impregnated with the Fume of burning Brimstone, so as to be preserved sound in an unfermented State. See *Must*.

Sublimation. Is the raising of a dry Body by Heat into Flowers, or a solid Cake, at the Top of the containing Vessel; being a Kind of Distillation suited to dry Bodies.

Subsidence. Is the suffering a Liquor to settle, and fine itself, by standing.

Sulphur. Is another Name for Brimstone; but in a more Technical Sense, denotes the fat, unctuous, or oily Principle in Bodies; or that Part of them, which is truly inflammable.

Thermometer. Is an Instrument contrived to measure the Degrees of Heat. Those made with Spirit of Wine, serve for the lesser Degrees, and those with Oil, or Quicksilver, for the greater.

Triture. Is the grinding, or rubbing any solid Body to Powder in a Mortar, or upon a grinding, or levigating Stone.

Torrefaction. Is the roasting, or scorching, of a Body by the Fire, in order to discharge a Part either unnecessary or hurtful, in another Operation,

ration; as Sulphur is discharged from an Ore, before the Metal can be obtained to advantage.

Turnsol. Is a red Colour prepared from the Juice of the Sun-Flower, and fermented Urine: which Colour being, in a fluid State, drank up by Linen-Rags, and dried, is the Thing sold by the Dry-Salters to the Dyers and the Wine-Coopers, for dying Cloths, and tinging Wines red.

Vitrification. Is the turning of a Body to Glass in the Fire.

Wash. Is the same Thing as fermented Wort, or any fermented Liquor, fitted to afford an inflammable Spirit, or Brandy, by Distillation.



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LECTURE I
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LECTURE I

CONTAINING

- I. *An Account of the Office and Objects of Chemistry.*
- II. *The Chemical Treatment of Bodies.*
- III. *Rules for making new Discoveries in the Art.*

I. **T**HE Design of these Lectures is to *The De-* enlarge the Bounds of Chemistry, *sign.* by applying it to the Advancement of Natural Philosophy, the Illustration and Improvement of the known Arts, and the Discovery of new ones.

2. In prosecuting this Design we would speak *The Man-* to the Eye, rather than the Ear; or indeed to the *ner of* Understanding, rather than the Senses; and by *Execution.* means of apposite Experiments, scientifically explained, lead to the Discovery of *Physical Axioms*, and *Rules of Practice* for producing useful Effects, in the way of a *Philosophical Chemistry*.

3. *Philosophical Chemistry* we define, a rational *Philoso-* Art of (1) dividing or resolving all the Bodies *phical* within our Power (2) by means of all the Instru- *Chemistry* ments we can procure; (3.) as well into integrant *defined.* as constituent Parts; and (4.) joining these Parts together again; (5.) so as to discover the Principles, Relations, and Changes of Bodies; (6.) make various Resolutions, Mixtures, and Compositions; (7.) find out the physical Causes of physical Effects; and (8.) hence improve the State of natural Knowledge, and the Arts thereon depending.

B

4. To

The Business of the Lectures.

4. To explain this Definition, in a concise general manner, is the Business of our first *Lecture*; and to illustrate it fully, will be the Business of all the rest.

5. Our Definition consists of eight Parts; the first whereof regards the *Objects of Chemistry*.

The Objects of Chemistry.

(1.) These *Objects* are all the Bodies within our Power. We should therefore, if it were practicable, take a particular View of the Contents of the terraqueous Globe. To abridge the Labour, we shall single out the more capital and useful Sorts; and range them in some Order, by way of Specimen, or Sample, of that grand Repository of infinite Materials*.

Classed.

The Productions of the Earth are divided into, I. *Minerals*. II. *Vegetables*, and III. *Animals*.

I. Minerals are subdivided into (1.) Metals and their Ores, (2.) Salts, (3.) Sulphurs, (4) Stones, (5.) Earths, and (6.) Semi-metals.

CLASS I. THE METALS are.

Gold,
Quicksilver,
Lead,
Silver,
Copper,
Iron,
Tin.

Ranged according to their specific Gravities, and compared with their Ores respectively.

II. SALTS. Alum,

Artificial Salt,

Bay Salt,

Borax,

Nitre,

Rock Salt, or Sal-Gem,

Sal Ammoniac.

* In the Course, a Set of Specimens was exhibited, in conformity with the following List.

III. SUL-

Of Philosophical Chemistry.

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III. SULPHURS. *Amber,*

Arsenic, white, yellow, and red,

Auripigmentum,

Bitumen,

Brimstone, Common,

———— *Native,*

Coal,

Jet,

Petreol.

IV. TRANSPARENT STONES.

From the *Diamond* to
Crystal.

} Ranged according to their
Hardness, which is their Cri-
terion, as Gravity is of Metals.

V. OPAKE STONES. *Alabaster,*

Amiantbus,

Emery,

Flint,

Hematites,

Loadstone,

Marble, and Porphyry,

Lapis Calaminaris,

Talc,

Tripoli, &c.

VI. EARTHS.

Bole,

Chalk,

Marl,

Ore,

Ocre,

Ruddle,

Terra Lemnia, &c.

VII. SEMI-METALS.

The Vitriolic are,

Vitriol, green and blue, viz. of Iron and Copper;

White Vitriol, with other foreign kinds.

VIII. The Sulphureous SEMI-METALS are,

Antimony,

Bismuth,

LECTURE THE FIRST.

*Cinnabar, native,
Mundick,
Pyrites,
Zinck, &c.*

II. VEGETABLES are divided into

*Herbs, Berries, Flowers, Fruits, Grains, Seeds,
Roots, Barks, Woods, Juices, and Excrecences.*

*Class I. HERBS. Angelica, Baulm, Hyssop, Ro-
semary, Lavender, Sage, Tan-
sy, Thyme, Wormwood, &c.*

*II. BERRIES. Bay Berries, Coffee, Kermes, Ju-
niper, &c.*

*III. FLOWERS. Jasmin, Saffron, Lillies, Mari-
golds, Roses, Elder-Flowers,
Violets, Flowers of Broom,
Holly-Oak, &c.*

*IV. FRUITS. Cocoa-Nuts, Nutmeg, Jamaica-
Pepper, Long-Pepper, Tama-
rinds, Cassia Fistularis, Pome-
granate, &c.*

V. GRAINS. Rice, Indian Wheat, Sago, Millet, &c.

*VI. SEEDS. Beech-mast, Cardamom, Gran. Paradis.
Mustard-Seed, Sun-flower Seed, &c.*

*VII. ROOTS. Alkanet, Galangal, Gentian, Liquo-
rice, Madder, Orris, Turmerick, &c.*

*VIII. BARKS. Cassia, Cinnamon, Clove-Bark, Cor-
tex Peruv. Mace, Oak-Bark, Winter's
Bark, &c.*

*IX. WOODS. Cedar, Guaiacum, Logwood, Rho-
dium, Saunders, &c.*

*X. JUICES are subdivided into natural, and ar-
tificial; or into Tears, and inspissated
Juices.*

*Tears, or natural Juices, of the Sycamore, the
Birch, &c.*

In-

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Inspissated Juices are divided into (1.) *Gums*, (2.) *Balsams*, (3.) *Rosins*, and (4.) *Sugars*.

(1.) **GUMS.** *Aloes, Gum Arabic, Assa Fetida, Ammoniacum, Benjamin, Bdellium, Galbanum, Gamboge, Mastich, Myrrh, Gum Elemi, Opopanax, Gum Sandarac, Gum Lac, Gum Tragacanth, &c.*

XI. (2.) **BALSAMS.** *Balsam Capivi, Opobalsamum, Balsam of Peru, Tolu, &c.*
The *Turpentine, Wax, &c.*

XII. (3.) **ROSINS.** *Camphire, Frankincense, Rosin of Guaiacum, Rosin of Jalap, Scammony, Burgundy Pitch, Common Rosin, Sang. Draconis, &c.*

XIII. (4.) **SUGARS.** *Honey, Manna, Sugar, &c.*

XIV. **EXCRESCENCES.** *Jews Ears, Agarick, Mistletoe, the Mosses, Galls, &c.*

III. ANIMALS.

Class I. ENTIRE ANIMALS. *Ants, Bees, Cantharides, Cochineal, Millepedes, Vipers, &c.*

II. **THEIR SOLID PARTS** *Bone, Hart's-horn, Ivory, Cuttle Bone, Elbow Hoof, Human Skull, Castor, &c.*

III. **CONCRETED ANIMAL JUICES.**

Goat's Blood and human Blood dried, Lard, Marrow, Sperma Ceti, &c.

IV. **EXCREMENTS.** *Album Græcum, Civet, Musk, Pigeon's Dung, Silk, &c.*

6. *Bodies* have been usually considered under three general *Classes*, called by the Names of the *Vegetable, Animal, and Mineral Kingdoms.* This Division is, perhaps, too scanty; as excluding many Particulars of the marine and atmospherical Regions. For in the Sea are found Coral, Shells, Sponge, Bitumen, Ambergrease, Mixtures of

Salt, Slime, Fæculencies, and the corrupted Parts of Fish, &c. which may possibly be irreducible to any of the three Kingdoms. And the Atmosphere abounds with Air, Light, Water, Meteors, Exhalations and Effluvia of the Earth, differently combined; so as not to appear distinctly either of a Vegetable, Animal, or Mineral Nature.

7. The *Objects of Chemistry*, therefore, are taken from the three larger Masses, or Regions, of the Globe; viz. the *Earth, Water, and Atmosphere*

The general Structure of the Earth.

8. Our Knowledge of the *Earth* reaches but a little below its Surface. So far as Men have dug, it appears a Compages of numerous solid Substances, ranged in a disorderly manner; which may be physically necessary, to afford different Partitions, or Beds, of Soil, Gravel, Clay, Stone, Coal, Marcasites, Ores, Gems, &c. each serving as a Matrix to the other.

Earth in particular.

9. By *Earth* is commonly meant the Soil, Mould, or Coat, wherein Vegetables grow. This Coat, which is but of little Depth, is the direct and immediate Seat of Vegetation. And with this *Earth* we chuse to begin our Experiments; proposing (1.) A general Analysis of Garden Mould; (2.) The Preparation of a general kind of Flux, for the assaying of Ores. (3.) The general Method of assaying Ores for their Metal. (4.) A general Analysis of common Water. (5.) A general Analysis of the Air. (6.) A general Example of the Method of reducing Bodies to their integrant Parts. (7.) A general Example of resolving Bodies into their constituent Parts; and (8.) An Example of Reduction, or the Method of recomposing, or recovering, Bodies after Solution.

II.

EXPERIMENT I.

The Analysis of Garden Mould, begun.

10. We took two Pounds of fresh, black and ^{*Earth*} rich Garden Mould, and stirred it well in two ^{*analysed.*} Quarts of fair Water, gently warmed, then letting the grosser Part settle to the Bottom, we filtered the Liquor thro' Cap-Paper; and found that it passed considerably muddy, or impregnated with the finer Parts of the Earth; which it would not easily deposite upon many Days standing in a quiet Place *.

11. The Design of the Experiment is to obtain a proper Liquor for discovering the Matter which the Earth affords to Plants in Vegetation, or the natural Juices, and natural Salts, of Garden Mould; because nothing seems capable of rising in Vegetation, but what is soluble in moderately warm Water, and will pass the Pores of Paper, somewhat in the same manner as it does the natural absorbing Vessels, or Strainers of a Plant. Whence the filtered Liquor of our Experiment may be examined by chemical Treatment; as by Evaporation, or the way of trying *Mineral Waters*, &c. as we shall see hereafter in our fourth Lecture.

12. Ores are the next useful Species of *Earth*; the general Treatment whereof, for obtaining their Metal, depends upon the Use of the *Black Flux*.

* See this Experiment carried a greater length in *Let.* IV. *Exp.* I. and II.

EXPERIMENT II.

The Method of making the Black Flux, for the assaying of Ores.

The Black Flux.

13. We took one Part Nitre, and two Parts common Tartar; and reducing each to Powder, we mixed them together, and deflagrated the whole in a Crucible, by lighting the Mixture a-top; which thus turns to a kind of *Alkaline Coal*, that is to be pulverized, and kept in a close Glass, to prevent its dissolving, as it would do in a moist Air.

14. This Flux is of general Use; and to have it ready at hand, shortens the Business of making Assays in Metallurgy; and renders the Operation more exact, than when crude Tartar and Nitre are employed; because the Deflagration might thus carry off some Part of the Ore, and defraud the Account. For the same Reason, the Mixture is here directed to be fired a-top; otherwise a considerable Part might be lost in the Deflagration; which would prove much more tumultuous and violent if the Matter was thrown into a red-hot Crucible.

EXPERIMENT III.

The general Method of analysing Ores.

Ores analysed.

15. We took two Ounces of Copper Ore reduced to Powder, and mixed it, in a Mortar, with twice its Weight of the black Flux; then, in a Wind Furnace, fused it briskly, that it might run thin, for about four Minutes: when, suffering the Crucible to cool, we broke it, beat off the Slag, and weighed the Metal.

16. This Experiment shews the Method of treating any unknown Ore, to discover, in the way

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way of Assay, or Proof, the Kind and Proportion of Metal it contains.

17. The Cause of the Effect depends upon a *The Ratio-
Separation of the terrestrial, sulphureous, or other* *naie of the
heterogeneous Parts of the Ore, which are here* *Process.*
either vitrified, or otherwise detained by the Flux; whose Property it is to vitrify Earth in the Fire, and strongly join with Sulphur; at the same time that it does not alter the Metal, but leaves it to its own nature; whence, by its superior Gravity, it sinks pure to the bottom of the Crucible; as being now made fluid, and set free from the heterogeneous Parts before mixed in among it a).

18. *Water* is generally divided into salt and *Water di-
fresh, with regard to the Ocean and Rivers.* *vided.*
But it seems divisible into as many different Species, as the Earth is into Beds. Thus there are Mineral Waters of various kinds, according to the Mineral Substances they run over, and become impregnated with: tho' this Impregnation sometimes happens in the way of Vapour, or Exhalation. Water, therefore, in the general, may be as mixed a Body, as Earth in the general; and perhaps neither of them naturally exists in any considerable Degree of Purity b).

EXPERIMENT IV.

A general Analysis of common Water.

19. (1.) We found that common warm Water *Water* throws up numerous Bubbles, and explodes, in *analysed.* the exhausted Receiver of the Air-Pump; and therefore contains what may, by way of distinction, be called Æther or Spirit.

a) See the Lect. on Metallurgy.

b) See *L.A.* V.

(2.) It

(2.) It contains a merely aqueous part, distinct from Æther, and from the Sediment; as appears in distilling common Water.

(3.) It contains a dry solid Matter, which is either earthy or saline, as appears upon a full Evaporation; and also from the Insides of Tea-Kettles, which, after long Use, are lined with a stony Matter, that beats off in Flakes or Crusts.

20. That Water is accounted best and wholesomest, which is lightest, most spirituous, and freest from earthy Sediment; and these Properties are usually found in pure Rain Water: this being naturally distilled, or raised by the Sun's Heat, from the Ocean and Rivers, into the Atmosphere, and from thence returned again, much after the manner of common Distillation *a*).

The Atmosphere divided.

21. THE *Atmosphere* is a kind of dry Fluid, no less essential to the Earth than the moist one. It seems as heterogeneous as the Earth or Water, tho' more rarified. It is dissimilar in its Parts, like the Body of the Earth; and has something analogous to Beds, or particular Portions abounding with different kinds of Effluvia, according to the Differences of the Countries and Places over which it extends. Thus over Mount *Ætna*, or other *Vulcanos*, it must necessarily be impregnated, after the manner of certain Mineral Waters, with the Fumes of burning Minerals; over the Island *Ceylon*, with Aromatic Effluvia; over *London* with the Smoke of Sea-Coal *b*), &c.

EXPERIMENT V.

A general Analysis of the Air begun.

The Air analysed.

22. A proper Analysis of the Air, or any integrant part of the Atmosphere, has hitherto scarce been attempted.

a) See *Lect. V.*

b) See *Lect. III.*

(1.) That

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II

(1.) That it is an elastic Fluid appears by its distending Bladders, and breaking Glasses, in the exhausted Receiver of the Air-Pump. (2.) That it is essential to Life, appears by Animals dying without it. (3.) That it may receive invisible Influences or Alterations, as well as visible Effluvia, appears from its becoming poisonous by passing thro' Fire; and by its containing gross Smoak, and the fine Particles of fermenting or putrefying Bodies: And (4.) that it is naturally a Compound, appears by the Water it deposits in dry Salt of Tartar; and by its changing the Colours of various Bodies, &c.

23. We shall hereafter attempt a more particular Analysis of the *Atmosphere*, in order to a Choice of the best Places for Health, Habitation, and the Exercise of particular Arts; on account of certain Properties in certain Places, arising from the different Mixtures, or Compositions, of the Air in different Parts a).

24. THE *Instruments of Chemistry* are all those we can any way procure b). There are several Instruments continually at work, for the immediate Production of Effects, in the three larger Masses, or Kingdoms, of the Globe, viz. the Earth, Water, and Atmosphere. We evidently find, that Metals and Minerals are formed within the Earth; Vegetables on its Surface, shooting into the Air; Meteors in the Atmosphere; and Men, Beasts, and Birds in the Confines of the two: The *Physical Causes* of all which are to be diligently sought out, as so many *Rules of Practice*.

25. The principal physical Agents in Nature appear to be, (1.) Heat. (2.) Cold. (3.) Air, or the integrant Parts of the Atmosphere. (4.) Water. And (5.) proper Beds, or *Matrices*. This is

a) See *Leç.* III. b) See above §. 3.

Matter

Matter of direct Observation; and might occasion the establishing of the four common Elements, Fire, Air, Water and Earth.

The Sun. 26. (1.) The *Sun* is the principal Source of Heat upon the Earth's Surface, and the Confines of the Earth and Atmosphere. Without this, all the Bodies upon our Globe would doubtless grow rigid, lifeless, and fixed. 'Tis this that stirs within them, as the main Spring of their Actions. Hence Vegetation, and Animalization, are evidently promoted; and hence the Ocean and the Atmosphere continue in a fluid State *a*).

Cold. 27. (2) *Cold* is correlative to Heat; and tho' perhaps no more than a less Degree, or Absence, thereof, yet has, in the natural State of things, an instrumental Efficacy; as in the condensing of Solids *b*), the coagulating of Fluids *c*), the separating of Salts *d*), Spirits *e*), &c. And by means of Cold and Heat, used alternately, it should seem that some capital Operations of Nature are performed, especially in the vegetable Kingdom, by the Reciprocation of Day and Night, Summer and Winter *f*).

Air. 28. (3.) Air, or any integrant Part of the Atmosphere, is an elastic Fluid, that expands with Heat, and contracts with Cold; so as apparently to generate Motion, and produce Effects. It animates Fire, and has a great Influence upon the Life of Animals: it also mixes in among, and unites itself with, Bodies; so as to constitute a material Part thereof *g*). It is the great Receptacle of

a) See *Let. II. passim.*

b) Which are rarified by Heat, but contracted by Cold.

c) As aqueous Liquors into Ice.

d) As Salt is separated in the Freezing of Salt-Water.

e) As Spirit is separated in the Freezing of Wine, urinous Spirits, and distilled Vinegar.

f) See *Let. III.*

g) See *Let. III.*

Effluvia from the Earth, the Matrix of Meteors, the continual Support of Birds, Beasts, Plants, and Men; and is in some degree nutrimental *a*).

29. (4.) *Water* is not only contained in the Earth, *Water.* as in a Reservoir, but likewise floats in the Atmosphere. In both Cases it is actuated, rarified, and put in motion by Heat; so as to prove instrumental in producing Effects. Thus it produces Clouds, Rains, Dews, Springs, and Rivers. It refreshes the Earth, recruits Vegetables, and is the Support of Fish and other Animals, by conveying Nutriment to all their Parts. It is also the first and immediate Instrument of Fermentation, Putrefaction, Corruption, and Change, in all vegetable and animal Subjects *b*).

30. (5.) Proper Beds, or *Matrices*, also appear *Matrices.* to have an instrumental Agency in the Production of natural Bodies. Every Subject of an Operation is necessarily contained in something that may (1.) afford it a Lodgment, (2.) make some Resistance, and (3.) convey to it Heat, Cold, Water, or Air, or determine their Actions upon it. Thus in Vegetation, the Matrix Earth supports the Seed, resists its Swelling, and conveys a strained, or prepared, Moisture to it. The *Matrices* of Gems and Ores not only afford a proper Lodgment to the Subject-Matter, but also resist its Growth, by the Pressure of their Sides; which, however, give way a little, and at the same time strain and convey suitable Juices to the Subject. And something of this kind is observed of the *Fœtus in Utero*, the Hatching of Eggs, &c. inso-much that Closeness, moderate Resistance, or a slow yielding of the Sides of the Matrix, and a straining of the Juices through them (unless sup-

a) As it adds to the Substance of Vegetables and Animals. See Mr. Hale's *Vegetable Statics*, and hereafter *Lect.* III.

b) See *Lect.* VII and XII.

plied from within) seem requisite for the Formation and Production of all Vegetable, Animal, and Mineral Substances. Whence we are furnished with a capital Rule for the Improvement of Chemistry, natural Philosophy, and Arts; and taught that, in order to imitate Nature, Chemistry must not be confined to the sole Use of Fire, as its Instrument, but occasionally employ Water, Cold, Air, Earth, and proper *Matrices*, or *Vessels*.

*Artificial
Instru-
ments of
Chemistry.*

31. But besides these *natural Instruments*, there is a great Variety of *artificial* ones belonging to Chemistry, which seem to raise the Power of this Art, in some respects, above the Power of Nature. Thus, by means of particular Menstruums, it performs Operations which Nature of herself does not: for instance, of all the Metals, only Iron and Copper are found naturally converted into Vitriol; whereas Chemistry makes Vitriols even of Gold, Silver, Tin, and Lead. And hence the Productions of Art may be much more numerous, than the Productions of Nature; indeed they may be increased at pleasure, to the great Enrichment of Arts, and the Enlargement of the Kingdom of Man *a*).

*Vessels,
Furnaces,
Utenfils.*

32. Another Set of Instruments belonging to Chemistry are *Vessels*, *Furnaces*, and *Utenfils*; of which there is a great Variety, for different Purposes, and capable of producing numerous Changes in Bodies, by Amalgamation, Cementation, Fusion, Fermentation, Putrefaction, Reduction, &c.

A new Set.

33. We add to the above-mentioned a new Set, viz. The *Air-Pump*, the *Condensor*, *Digestor*, *Microscopes*, *Burning-Concaves*, *Prisms*, *Lenses*, *Portable Furnaces*, and every other Instrument that can be invented, or procured, of advantage to the Art.

a) In this Light may the numerous Productions of the Chemical Trades be consider'd; such as the Effects of Fermentation, Distillation, Dying, Soap-making, the Art of Glass, Metallurgy, &c.

34. THERE are two capital Ways wherein Chemistry divides its Subjects, by the several Instruments above-mentioned; viz. into *integrant Parts*, and into *constituent Parts*. By *integrant Parts* we understand similar Parts, or Parts of the same nature with the Whole; so Filings of Iron have the same Nature and Properties as Bars of Iron. Under this general Operation, fall those particular ones of Triture, Filing, Solution, Amalgamation, Sublimation, &c. And by *constituent Parts*, we mean dissimilar Parts, or Parts of a different Nature from the Whole; as when artificial Cinnabar is divided into Quicksilver and Sulphur: and under this general Operation come all kinds of Analyses or Resolutions.

Two principal kinds of chemical Division.

EXPERIMENT VI.

A general Example of reducing Bodies into their integrant Parts.

35. We took an Ounce of Quicksilver in a small Glass, and poured upon it two Ounces of *Aqua fortis*; then set the Glass in a Sand-Heat to warm: red Fumes soon appeared; and the Mercury, or Quicksilver, disappeared. We added a little more Mercury, till a small Particle was left undissolved at the Bottom, that the Solution might be saturated. Then we decanted the clear Liquor: a Drop of which being viewed in a Microscope no Particles of the Mercury appeared separate.

Quicksilver rendered invisible by a minute Division into integrant Parts.

36. Here we find the opaque and heavy Body of Mercury transparently dissolved, and equally diffused in a Fluid, at least ten times lighter than itself; the Mercury still remaining unaltered and recoverable in its pristine Form, barely by Collection or Aggregation, as we shall presently see a): so that it is thus only divided into homo-

a) Under Experiment VIII.

geneous

geneous or integrant Particles, and not separated into Particles of different Kinds.

EXPERIMENT VII.

A general Example of resolving Bodies into their constituent Parts.

Brandy resolved into its constituent Parts.

37. We gently distilled two Gallons of common Brandy by the *Balneum Mariæ*, which resolved it into Spirit of Wine and Water. For the Spirit of Wine, being the lightest Part, comes over first, and leaves a large Proportion, or about one half, of Water or Phlegm in the Still.

38. And thus Brandy is separated into the two very different, or heterogeneous Parts, whereof it consists. And hence, by the way, all Rums and Brandies contain one half Water, no way essential to them, that might commodiously be left behind upon their Transportation and Carriage. And this holds still stronger of Arracks, which usually contain three fourths Water, to one of Spirit *a*).

Aggregates and Mixts, what.

39. These two general Operations of Chemistry bear relation to two general Structures of Bodies, viz., the *Aggregate* and the *Mixt*. Aggregates in their Resolution constantly retain their Nature in every the smallest Part, or Atom; but when Mixts are resolved, the Mixture is destroyed, and two or more new Aggregates are produced: thus when Brandy is resolved, Spirit of Wine or *Alcohol*, and *Water* are produced.

Sensible Bodies composed of insensible.

40. Every sensible Mixt, or Aggregate, is composed of many insensible ones. Before Gold can become sensible to us, there must be a Collection of numerous Parts that are separately insensible; yet all of them perfect Gold. The

a) See *Leß. VII. Exp. IV.* and *Leß. XII. Exp. IV.*

minuteft

minute Grain of Cinnabar has in it two different Parts, Sulphur and Quicksilver. The minute Grain of Glass contains Sand and fixed Salt. And so when Quicksilver is dissolved in *Aqua Fortis*, the least assignable Portion of the Menstruum contains a Quantity of Mercury proportionable to the whole.

41. (4.) Either the integrant or the constituent Parts of Bodies being once divided or dissolved *a)*, various Occasions in Chemistry require them to be united again, for composing a Whole like the original Subject. This Operation is the Converse of the former. Thus by simple Mixture we recompose Brandy from Alcohol and Water; and by Precipitation with a Copper-Plate, collect the Quicksilver dispersed in *Aqua Fortis*. *Recomposition illustrated.*

EXPERIMENT VIII.

An Example of the Method of recovering Bodies after Solution.

42. Dilute part of the above Solution of Quicksilver *b)* with twice its quantity of fair Water; suspend a Plate of Copper in the Liquor; the Quicksilver will soon fall in its natural Form to the bottom of the containing Glass, and being then taken out, well washed and dried, will be absolutely indistinguishable from other Quicksilver that has never been dissolved. The Effect is owing to this, that *Aqua Fortis* dissolves Copper more easily than Quicksilver, and so lets the Quicksilver fall in proportion as it dissolves the Copper. And this, by the way, is a general Example of *Precipitation*. *Quicksilver recovered.*

a) See above, §. 3.

b) Exp. vi.

The Principles, Relations, and Changes of Bodies, how discoverable.

43. (5.) To discover the Principles and the Relations of Bodies, and the Changes *a)* produced in them by the Operations of Philosophical Chemistry, we must use all our Senses, assisted by proper Sets of Experiments, or particular Ways of Examination; otherwise we shall learn but little of the Powers of Nature and Art. In the Experiment of Quicksilver dissolved in *Aqua Fortis*, we find by a slight Expedient, *viz.* by putting a piece of Copper into the Solution, that the Quicksilver, tho' rendered invisible, is not destroyed; seeing it is thus recovered in its pristine Form and Properties.

44. By casual Experiment, *Glauber* discovered his Method of preparing mineral acid Spirits by means of Oil of Vitriol: for having once obtained this Oil, by an Analysis of Vitriol, he applied it to the Mineral Salts, and found that it expelled their volatile Acids in Fumes; and that these being more plentifully raised by Heat, and collected again, made the acid Spirits, so useful in Metallurgy, Refining, Dying, &c. Thus one new chemical Production may give Rise to many new Arts.

The Resolutions and Compositions of Chemistry.

45. (6.) The Resolutions and Compositions made by Chemistry *b)* are extremely numerous, and may be increased *ad infinitum*. We exhibited an Instance of Resolution in the Analysis of Brandy: And to this Class of Resolutions are referable all kinds of Depurations, Purifications, Separations, Clarifications, &c.

The Productions of Composition.

46. By Composition we produce all the artificial Vitriols, Soaps, Glasses, &c. and can compound these again in an almost infinite Variety. So that the Resolutions, Compositions, and Recompositions in Chemistry, seem to have

a) See above, §. 3.

b) Ibid.

no Bounds; whence great room is left for new chemical Discoveries.

47. (7.) Whilst we carefully attend to the several Steps of chemical Operations, we are led into some sort of Knowledge of the *Physical* or *Material Causes* of the Effects ^{*The Physical Causes of chemical Effects.*} *a)* produced, as may appear from our Attempts to assign the chemical *Causes* in the foregoing Experiments. Hence the more Attention and Diligence we employ, the juster Notions shall we have of these Causes, or the nearer Approaches shall we make to the Discovery of them; and they being once certainly found will afford us certain *Rules of Practice*, to be occasionally employed for producing the same Effects again. For to discover the Cause of an Effect, is to discover a Rule for producing that Effect.

48. (8.) The Improvement of natural Knowledge, of Chemistry itself, and of the Arts thereon depending *b)*, must be the Consequence of a due Prosecution and Improvement of *Philosophical Chemistry*; which for Distinctness sake, we shall hereafter consider, as it more immediately relates to (1.) *Fire*, (2.) *Air*, (3.) *Earth*, (4.) *Water*, (5.) *Menstruums*, (6.) *Fermentation* and *Putrefaction*, (7.) *The Analysis of Bodies*, (8.) *The Synthesis of Bodies*, (9.) *Vegetable Curation*, (10.) *Vinous and acerous Fermentation*, (11.) *Distillation*, (12.) the making of *Oils*, (13.) *Salts*, (14.) *Colours*, *Dyes*, and *Stains*, (15.) *Pharmacy* and *Medicine*, (16.) *Mineralogy*, (17.) *Metallurgy*, (18.) *Pyrotechny*, and (19.) the farther *Uses of Chemistry*: so as to shew what has already been done on these Subjects, carry the View somewhat further, and recommend a fuller Prosecution to others. ^{*The Advantages of improving Chemistry.*} ^{*The Subjects to be treated in the following Lectures.*}

a) See above, §. 3.

b) Ibid.

Three general Rules
for conducting
Philosophical
Chemistry.

49. It was said in our Definition *a*), that Philosophical Chemistry is a *rational Art*; by which we mean that it may be conducted by Rule, and need not be left to accidental Trial and casual Experiment. The Rule for duly conducting the Art we would endeavour to comprize under the following three.

III.

RULE I.

50. When a Body is offered, in order to have new Properties discovered in it, different from those general ones of Figure, Gravity, Elasticity, &c. which come under Mathematical Consideration, let the Body be resolved, by degrees, into the simplest constituent Parts, which it is capable of being separated into by the Instruments above described: And let Trial be made with each particular part, on a variety of Bodies, according to some Analogy of a previous Chemical Knowledge, leading from one thing to another, in a sure or probable Method of Ratiocination.

RULE II.

51. Let the several Parts, obtained by the preceding Analysis, be reunited, beginning with two, and proceeding gradually to the whole Number; using at first the gentlest, then the intermediate, and at last the highest Degrees of Heat and Cold. Thus, for example, join the fixed Salt and Oil of a Plant together, first by simple digestion, and afterwards by boiling; which affords a third Production dissimilar to all the rest, and known by the Name of Soap. So, again, melt the same fixed Salt with the Earth of the Plant; and this will afford Glass.

a) See above, §. 3.

Of Philosophical Chemistry.

21

Let the last Attempt be to reunite all the separated Parts of the Body; in order, if possible, to form the original Substance again.

RULE III.

52. In every Operation performed let the greatest Diligence and Exactness of Observation be used, with regard to all the principal Phenomena and Effects produced; let these Phenomena be duly register'd, tabled, considered, and compared together, after the strictest Geometrical Manner; the Result whereof, if there be no considerable Errors committed, will lead to a Knowledge of the secret Springs, Motions, Instruments, and Means made use of by Nature for producing Effects. And thus, with proper Care and Application, just Canons or Rules of Practice may be formed.

53. The Art of Chemistry having been but little cultivated in this view, all we can at present pretend to, is to make some Offers at forming such Canons or Axioms, and consign them over to further Experience and Observation, to be thereby verified, amended or rejected. But if a competent number of just Axioms and Canons were once formed in this manner, others of a still higher nature might be raised from them; till at length, Practice and Experience would lead us to a true Theory; and that Theory back again to a more extensive and useful Practice.

IMPERFECT AXIOMS, or CANONS, deduced from the preceding Enquiry, for promoting farther Discoveries and Improvements in chemical and natural Knowledge.

54. (1.) *We may learn from our present Enquiry, that a true Chemistry (as it may perhaps be justly called) is exercised by Nature in the Vegetable, Animal, Mineral, Marine, and Atmospheric Regions; and that by it all Bodies are produced, converted, renovated, repaired, and maintained: and that in the exact Discovery, Imitation, and Controul of this natural Chemistry, consists the Perfection of the artificial a).*

(2.) *That neither the Eye, nor all the Senses together, can give us any Information of the latent Properties of Bodies, their Natures and Uses, without particular Tryals and Experiments, well attended to and considered b).*

(3.) *That Experiments are but insignificant Facts, unless they have a direct Use in Life, or tend to the raising of Axioms and Canons, for improving our Knowledge, and extending our Power over the Works of Nature c).*

(4.) *That he who can chuse fit Subjects, place them in proper Matrices, or including Vessels, and supply them duly with Air and Water, Heat and Cold, may probably produce great effects in Imitation of Nature d).*

(5.) *That nature points out three Matrices for producing Physical Effects, different in Fineness, viz. Beds of Earth, Beds of Water, and Beds of Atmosphere: Beds of Earth for Minerals, of Water for Fish, and of Atmosphere for Birds,*

a) See above, §. 7, 8, 9, 21, 24, 25.

b) See above, §. 35, 36, 38, 39, 41.

c) *Passim.*

d) See §. 24, 25, 26, 27.

&c; The Confines of the Earth and Atmosphere for Plants and Animals; and a rarified Mixture of all Matters for Meteors. a)

(6.) That Men may make use of the same Instruments as Nature does, viz. Fire, Air, Water, and Earth, and consequently produce the same kind of Effects, if Skill, that is, Knowledge, be not wanting. Whence to improve in Knowledge, is to improve in Arts b).

(7.) That Chemistry is not confined to the Use of Fire only; but, in imitation of Nature, may employ Cold, Air, Water, and Earth upon Matter, in various Degrees of Simplicity, Combination, and Mixture; which shews an extensive Method of enlarging the Bounds of the Art c).

(8.) That Fire is not only an Analyser in some Cases, but also a Mixer of Bodies in others; and this to the Advantage of Chemistry: For if it only separated, it could produce but few Effects, in comparison of that infinite Variety it now produces, both by Mixture and Separation d).

(9.) That it might be proper to try the Reciprocation of Heat and Cold in Chemical Operations, after the manner of Nature, in Day and Night, Summer and Winter e).

(10.) That Body, in all its Forms, is the Object of Chemistry; not considered mathematically, nor mechanically, but operatively and effectively f).

(11.) That the Atoms, or primary small Corpuscles of Bodies, are insensible to us: Thus the first Particles of Gold, Salts, Metals and Minerals may float in the Air, and not be perceived by us,

a) See § 25. b) See § 25, 26, 27. c) Ibid.

d) See § 28—45. e) See § 25. f) See § 3, 5, 7, 49, & alibi passim.

till they aggregate or are collected together, and make a sensible Mass, or produce a sensible Effect a).

12. That some Operation of the Mind is requisite to digest, methodize, and register Chemical Experiments and Observations; without which we cannot come to know the Laws observed by Nature in Physical Operations, nor be able to imitate them: The Chemistry, or regular Processes, of the Mind being here as necessary, as the corporeal Operations themselves b).

a) See § 35, 36, 38, 39, 41.

b) See §. 3, 48, 49, 50, 51.

More Canons and Axioms might be drawn both from the present *Lecture*, and from all the following; but the Design of drawing any at all, is chiefly to recommend the Method, rather than the Matters brought a second time under consideration.



LECTURE II.

CONTAINING

- I. *The Nature, Properties, Office, and Use of Fire in general.*
- II. *The Nature of Celestial, Subterraneous, and Culinary Fire.*
- III. *The Effects of Fire on the Atmosphere, and Bodies of the terrestrial Globe.*
- IV. *The Degrees of Heat regulated.*

I.

1. **O**UR present Design is to search into the *The present*
 Nature of Fire: This we shall attempt *Design.*
 by means of Experiments, conducted
 after the manner laid down in our first Lecture.

2. All the physical Knowledge we can have *Prelimi-*
 of a Subject must arise from attending to its *nary Ob-*
 Properties and Effects. But these Properties *servation.*
 and Effects can never be discovered without the
 help of Experiments, which in physical Enqui-
 ries are the only Interpreters between our Senses
 and our Reason. Whence all those Notions of
 Fire should be rejected as precarious and un-
 sound, that are taken from the direct Testimony
 of the Senses only, or from bare Reasoning un-
 assisted by Experiments. In this Enquiry, there-
 fore, the Mind is carefully to be kept unprepof-
 fessed, and to wait for a full and proper Infor-
 mation before it pronounce.

3. By the general Name of *Fire* Men seem to *Fire, how*
 understand a certain Sensation, or complex No- *understood.*
 tion

tion of Light, Heat, Burning, Melting, &c. This Notion should be resolved or analysed, in order to see what Parts thereof are essential, and what precarious or arbitrary.

*The Eye no
judge of
Fire.*

4. We frequently find the Effects of Fire produced where no visible Fire appears. Thus the Fingers are easily burnt by an Iron heated below the Degree of Ignition, or so as to be no way visibly red-hot or fiery; whence the Eye is no Judge of Fire.

*The Touch
no true
judge
thereof.*

5. So likewise the Touch gives us no positive notice of any Degree of Fire below the natural Heat of the Body, or of any so great as to destroy the Organ.

*Burning,
&c. not es-
sential to
Fire.*

6. Again, the Effects of Fire are often produced without any manifest Signs of Burning, Melting, &c. as in Evaporations, Exsiccations, &c.

7. If this Method of Exclusion and Rejection were pursued to its due length, we should perhaps find no Criterion, infallible Mark, or Characteristick of Fire in the general, but that of a particular Motion, struggling among the small parts of Bodies, and tending to throw them off at the Surface. If this should prove the Case, then such a Motion will be the *Form* or *Essence* of *Fire*, which being present makes Fire also present, and when absent makes Fire also absent. Whence to produce Fire, and to produce this Motion in Bodies, will be the self-same thing *a*).

8. But the following Experiments will afford us more Light, and shew, (1.) That, in general, both Solids and Fluids manifest an expansive Motion upon being heated; (2.) That the direct inflammable Matter of Fuel is Oil, or an unctuous

a) See Lord Bacon's Philosophical Works, English Ed. Vol. II, pag. 433, &c.

Substance; (3.) That no Fuel will burn or consume without the Admission of fresh Air; (4.) That the Air, which has once passed through burning Fuel, is of itself unfit to animate Fire again; and, (5.) That Flame exists only on the Surface of Fuel.

EXPERIMENT I.

That Iron expands with Heat.

9. We procured an Iron Ring to be made, just capable of admitting one end of a solid Rod of the same Metal; then heating that End in the Fire till it was red, and applying it to the Ring, we found the Rod so swell'd, that it would not now enter the Hollow which it fitted exactly when cold.

10. This Experiment directly shews no more than that Iron expands upon being heated; but as it has also been found to succeed in many other Solids, it may be made general, till the contradictory Instances are produced in the way of Exceptions *a*).

EXPERIMENT II.

That Fluids expand with Heat.

11. We filled the spherical Cavity of a bellied Glass, having a long and slender Neck, at three different times, with (1.) Mercury, (2.) Water, and, (3.) Spirit of Wine, to the same height; then plunging the Glass, successively, into Water (kept in the same Degree of Heat, in all the three Trials, as appeared by a Thermometer) we found that each Fluid swelled very remarkably, or rose up to a considerable Height in

a) Cedar Wood has, upon some Trials, been thought not to expand with Heat, or contract with Cold.

the

the Neck of the Glass, above what it stood at before the Glass was placed in the hot Water.

12. This Experiment seems to hold of Fluids universally : so that for the present we may allow the Motion of Expansion, or Rarification in Bodies, to be inseparable from Heat, or Fire in the general.

II.

Three Kinds of Fire. 13. We proceed to consider this *general Fire* in its three Kinds, viz. *Celestial*, *Subterraneous*, and *Culinary*.

Celestial. 15. By *Celestial Fire* we principally mean that of the Sun, without regard to the Fire of the fixed Stars ; tho' this perhaps may be of the same nature.

Subterraneous. 15. By *Subterraneous Fire* we understand that which manifests itself in fiery Eruptions of the Earth, Vulcanos, or burning Mountains ; and by any other Effects it produces in Mines, or the more central Parts of the Earth.

Culinary. 16. By *Culinary Fire* we mean that vulgarly employed in all Chemical Operations, and the common Occasions of Life.

The Sun's Heat. 17. The Sun's Heat appears to be the actuating Principle, or general Instrument of all the Operations of Nature in the Animal, Vegetable, Atmospherical, Marine, and Mineral Kingdoms *a*).

The Purity of the Sun's Heat. 18. Considered in itself, Fire seems to exist in greatest Purity and Perfection in the Celestial Regions ; at least we are not sensible of any Smoke it yields : for the Rays of Light come to us from the Sun, unmixed with any of that gross, terrestrial Matter found in Culinary and Subterraneous Fires. But allowing for this Difference

a) See *LeA.* I. §. 16.

the Effects of the Solar and Culinary Fire appear to be the same.

19. The Effects of *Subterraneous Fires* will also be found nearly the same with those produced by Culinary Fire. Burnt Coals, Cinders, and melted Minerals are thrown up by *Vesuvius*, and other *Vulcanos*. Warm mephitical Exhalations, natural hot Springs, Steams, Vapours, Smoke, &c. are found in several parts of the Globe, rising much in the same manner as if they were produced by the Heat of a Furnace. Whence it can scarce be doubted that Subterraneous Fires are of the same nature with the Culinary.

Subterraneous Fire approaches the Culinary.

20. And as all the three kinds agree in giving the Motion of Rarification to Bodies, it seems no way improper to reduce them to one; or to quit, for the present, the Celestial and Subterraneous, and keep to the Culinary Fire, which is more within our power, and every where ready at hand to be employed in Experiments.

The three Kinds have a near Agreement.

21. All Culinary Fire requires some Pabulum or Fuel, wherein it either resides or is collected. A leading Experiment therefore, in our present Enquiry, is the Analysis of Fuel; to discover its constituent Parts, and learn which of them is more immediately adapted to receive or propagate Fire.

Fuel what.

EXPERIMENT III.

That Oil is essential to Fuel.

22. We put a Pound of common Billet Wood, reduced to small Pieces, into an earthen Retort, and distilled with a naked Fire into a large Glass Receiver. There came over (1.) an acid Water, (2.) a redish tart Liquor, (3.) Smoke, and a gross

A leading Experiment.

gross, black, burnt Oil. The fire being made and kept up strong at last, no more Liquor or Oil ascended; but (4.) a black Matter, exactly resembling Charcoal, remained behind: this being taken out and burnt in the open Air, fell into Ashes; which by Dissolution in Water afforded (5.) a little fixed Salt, and (6.) an earthy Substance.

*That Coals
owe their
Inflamma-
bility to
Oil.*

23. This Experiment appears to be general, or to succeed alike in all Wood, Coals, or solid Fuel. We separated the acid Water or reddish Liquor from the Oil by the Filtre; and then found that these aqueous Liquors would not burn in the Fire; no more would the Ashes, the Salt, or the Earth, either singly or in composition: so that of all the Substances thus obtained from the Wood, the black Coal and the Oil are the only inflammable ones. But the Coal remains inflammable merely upon account of the gross Oil still lodged and closely locked up therein, and according to its peculiar nature, scorched, or turned black by the Heat employed in the Operation.

24. If farther Evidence be wanted to prove that the Oil remaining in the Coal gives it its Blackness and Inflammability; let it be considered, (1.) That all scorched Oils turn black; and that the more volatile Oil, which here comes over into the Receiver, is black. (2.) That no other part of the Wood, separated by the Analysis, is inflammable, besides the black Oil; not the Coal itself after it is become white or reduced to Ashes by open Fire and Air, which is an Operation sufficient to dislodge the gross black Oil, that could not be raised by a less Force. (3.) That no other chemical Cause can well be assigned for this Blackness and Inflammability. (4.) That Wood, Pit-Coal, &c. prove less inflammable,

mable the more they are deprived of their Oil. (5.) And lastly, that the Calces of Metals, rendered absolutely unflammable by Calcination, appear to attract this Oil out of burning Fuel, so as thence to recover their inflammable Principle and true metalline Form *a*).

25. But without farther Proof we may venture, for the present, to constitute Oil the sole Principle, or inflammable Matter in Fuel; and on this footing it will be proper to reduce our Enquiry to the more oily Species of Bodies, and make our Experiments chiefly upon those.

EXPERIMENT IV.

That Fire will not consume Fuel without the Admission of Air.

26. Having exactly fitted a hollow Cylinder of Iron with a strong Skrew at each end, we included a long Piece of Charcoal in the Cavity; then skrewing both ends tight, we detained the Cylinder in a strong Fire for several Hours; letting it afterwards cool and taking out the Charcoal we found it still black and no way apparently consumed, altered, or diminished.

27. This Experiment, compared with the common Observation that Fuel burns and consumes quickly in the open Air, shews that Air is necessary to the Consumption of Fuel; or that its burning and consuming depend upon the Rarification, Dislodgment, brisk Agitation, and Discharge of the Oil it contains; which is the physical Cause of the Effect. And hence we have the

a) Let proper Trial be made, whether the fixed Oil cannot be separated from powdered Charcoal by a strong Lixivium of Pot-ash and Quicklime, so as to form a Soap, or otherwise exhibit this Oil to the Eye. See *Let. XVIII.* §. 22.

reason of the known Rule or Method of extinguishing Fire by smothering it, or keeping it close from the Air.

28. But that the bare Motion of confined Air, or its passing several times through lighted Fuel, is not capable of consuming it, appears by the following Experiment.

EXPERIMENT V.

That Air which has passed thro' Fire, or ignited Fuel, is unfit to animate Fire again.

29. We caused a wooden Box to be made, perfectly close and tight, with Glafs Windows on the sides. At the bottom of this Box was a Perforation exactly fitted with a hollow wooden Plug, that joined to a tight leathern Pipe. This Pipe at the other end communicated with the Clack of a pair of Hand-Bellows, the Nose whereof entered at a Hole on one side of the Box; so that by this Contrivance it was easy to draw the Air out of the Box into the Cavity of the Bellows, and return it into the Box again, without admitting any other Air besides that originally contained in the Box. We now set a little Chafing-Dish of live Coals in the middle of the Box, and securing all the Joints tight from the external Air, we plied the Bellows; which, instead of increasing soon totally extinguished the Fire; tho' the Coals were by no means burnt to Ashes, but remained black and fresh when cold.

30. Hence it is manifest, that even a brisk Motion of such Air as has already passed through burning Fuel, is so far from animating, that it deadens or quenches Fire *a)*, in the same manner

a) Let a proper Experiment be devised, to shew what Alteration the Air suffers by passing through Fire.

damped or smothered; the Oil of the Fuel not being carried off for want of fresh Air.

31. This method of damping Fuel, or suffering it first to burn a little and then extinguishing it, teaches us a Method of rendering Fuel inoffensive and fit for the more curious Uses, by discharging its gross Smoke, so as to leave a pure charred Coal behind. *Fuel, how charred.*

Thus for example, if Pit-Coal or Wood be burnt, not in the open Air, but with a cover'd, close, or mouldring Heat, till it ceases to fume, and be then immediately quite smothered or quenched by throwing on it Mould, Sand, or Water, it becomes a charred Coal or Coak, fit for the drying of Malt, or other curious Operations in which gross Smoke would be prejudicial.

32. Another Method of obtaining a pure Fuel is to chuse such an inflammable Matter as yields little or no Smoke from the first; such, in particular, is Spirit of Wine; or, in the next Degree, Oil of Turpentine, or other thin *ethereal Oils*, as they are called; whereof Spirit of Wine is by the Chemists deservedly reckoned the finest or most subtile *.

EXPERIMENT VI.

That Flame dwells and plays only about the Surface of Fuel.

33. We filled a Lamp-Glass with Spirit of Wine, and another with Oil of Turpentine; then setting fire to each it was visible thro' the Glasses that both Liquors burnt or flamed on the Surface only; the Flame continually sinking lower and lower in the Glasses as the Liquors consumed.

* See *Let. VI.* and *XIII.*

34. This Experiment holds also of solid Fuel, and appears to be universal. And hence again we are directed in the choice of our Fuel; which, to light quick, should be furnished with a thin subtile Oil on its Surface. Upon this principle depend those sudden Methods of Illumination practised at great Entertainments or publick Rejoicings; and upon the same Principle we might easily invent quick, commodious, and inoffensive Ways of lighting common Fires, &c.

III.

*The Effects
of Fire.*

35. Having learned how to procure, prepare, manage, and improve our Fuel *a)*, we come next to consider the Effects of Fire, produced by means thereof, on the Atmosphere and Bodies of the terrestrial Globe.

*On the At-
mosphere.*

36. All Fire rarefies the Air that is near it, as appears from a Bladder including a small Portion of Air, and lying in a warm Place; for thus the Air is made to swell and distend the Bladder: Whence the Atmosphere must needs be rarefied by the Sun's Heat, and produce Effects accordingly. The Air also imbibes Smoke and carries it aloft, at the same time that the Fuel diminishes or wastes and falls into Ashes. Whence the Air becomes a kind of Menstruum, impregnated with Smoke or the matter of Soot, in Places where much Fuel is consumed *b)*.

*On par-
ticular
Bodies.*

37. The Effects of Fire upon particular Bodies can only be learned from particular Experiments; to make which, is the more immediate Office and use of Philosophical Chemistry. Thus in some Bodies, as Ores, Fire procures Fusion

a) See above, § 25, 26, 27, 28, 29, 31, 32, 33, 34.

b) See *Lect. III. passim.* See also *Lect. I. §. 16.*

and Separation; in others, as Sand and Pot-ash, Fusion and Mixture; in some Dryness and Exsiccation, as in Clay; in others Softness and Pliability, as in Wax, &c. according to the Degree and Manner in which the Fire is applied. But for the Conduct to be observed in this Application certain general Rules are required. And first with regard to the kinds of Heat:

38. There are in Chemistry as many kinds of Heat as there are Mediums thro' which it may be conveyed, or Fuels that afford it. *The kinds of Heat in Chemistry.*

39. For common use, Heat is conveyed either thro' Water, Ashes, Sand, &c. or directly thro' the containing Vessel,

40. When Heat is conveyed thro' Water it is called the *Balneum-Mariæ*, or Water-Heat; when thro' Ashes, an Ash-Heat; when thro' Sand, a Sand-Heat; and when thro' no intermediate Substance at all, a naked Fire. *Balneum Mariæ, Sand-Heat, &c.*

41. Some Differences may be found in the Effects produced by these different Heats applied in the same Degree: but they have not perhaps been noted as they deserve.

42. In several Bodies 'tis evident that dry and moist Heats have different Effects; as we find remarkably in the common culinary Operations of boiling, roasting, baking, &c. And hence, where the Effects are required perfectly similar, the same kinds as well as degrees of Heat are to be used.

43. The purest Fire is that of Alcohol or perfectly pure Spirit of Wine; the next in Purity is that of distilled Oils; the next, that of Charcoal, or charred Turf; and the impurest, that of Pit-Coal: But all these have nearly the same Effect, when received thro' the same kind of Medium. *The Degrees of Purity in Chemical Fires.*

IV.

The Degrees of Heat.

44. The last thing to be considered is, how to regulate and ascertain the Degrees of Heat in Chemical Operations, so as to produce the Effects required in every Case.

Uncertain.

45. The common Directions of the Chemists about this Matter are full of Uncertainty; their first, second, third, and fourth Degrees of Heat, meaning no precise Degrees measured by any Standard.

How to be regulated.

46. To reduce this Affair to the necessary Accuracy proper Thermometers might be employed, filled either with Oil or Quicksilver, and graduated from the freezing Point, or any other fixed Point of Cold, up to the Degree of boiling Quicksilver. Thus would come in their respective Places, (1.) the Degrees of Heat best suited to Vegetation, which might be serviceable in regulating the Temper of Green-Houses. And this temperate Heat is fit for extracting the native Spirits of odoriferous Vegetables with Oil; as of Roses, Jasmin, &c. and again, for making the more curious Insolations, &c.

The first Degree.

The second.

47. (2). The next Degree of Heat may be accounted that of the human Body in a healthy State, which is always greater than that of the ambient Air. But when the Body is dead, it receives the same Degree of Heat with the ambient Fluid. This second Degree of Heat is adapted to vinous and acetous Fermentation, Putrefaction, Exclusion of the Chick; the finer Digestions, the making of Tinctures and Elixirs; and the Adepts have used it for the first Digestion of their Mercury, by carrying the including Vessel constantly in their Pocket.

48. (3.) The third Degree of Heat in this *The third.*
 Progression may be that of boiling Water, when
 the Atmosphere is in a middle State of Rarefac-
 tion. This Degree is required in the Distilla-
 tion of simple and compound Waters, the essen-
 tial Oils of Vegetables, and will coagulate or
 consolidate the Serum, Blood, and other animal
 Juices, and consequently destroy animals.

49. (4.) A fourth Degree of Heat may be *The fourth.*
 that wherein Quicksilver or Oil of Vitriol boils,
 distils, or becomes volatile. This Degree is
 suited to the melting of Lead, Tin, Bismuth,
 &c. the subliming of Sal Ammoniac and Sul-
 phur; the calcining of Antimony, &c.

50. (5.) A fifth Degree of Heat may be that *Fifth.*
 wherein Iron is kept in thin Fusion. By this
 Degree all the other Metals are melted, viz.
 Gold, Silver, and Copper; Glass is made, and
 the unvitriifiable Stones calcined.

51. (6.) The sixth and highest Degree of Heat *Sixth.*
 hitherto known, is that of the burning Lens, or
 the Concave Mirror of M. Villette, Tschirnhausen,
 and others. The Focus of these Glasses will even
 volatilize what is called the Metalline or Mercuri-
 al part of Gold, and vitrify the more ter-
 restrial.

52. And thus much for regulating the De- *The De-*
 grees of Heat to be employed in Chemical Ope- *degrees of*
 rations. We must next consider by what means *Heat, how*
 the preceding Degrees of Heat may be excited *raised and*
 and preserved, as Occasions require. *preserved.*

53. (1.) The Fuel must be chosen suitable to
 the Intention. The natural Sun in Summer suf-
 fices for Insolations. A Spirit-Lamp may be
 made to give a moderate, or a considerably strong
 Heat, according to the number of Wicks em-
 ployed; and its Strength may be easily mea-
 sured and adjusted by the Thermometer.

54. (2.) The lighter Fuels, such as Straw, Leaves, Twigs, &c. come next in order after Spirit of Wine. (3.) Then Oils, Wax, Rosin, Pitch, &c. And, (4.) Lastly, solid Wood, Coals and Turf; all which may have their proper Furnaces, so as to be burnt in the requisite Quantity and with the requisite Fierceness or Slowness.

The greatest Heat with Fuel.

55. To excite the greatest Degree of Heat in a Furnace the Rule is, to use the densest Fuel, in the largest Quantity, and with Bellows all round the Furnace, incessantly blown, and directed to the central Point of the Fire wherein the Matter to be acted upon is lodged. And in this manner may be procured a Degree of Heat sufficient for any of the known Operations upon Metals, Minerals, Glass, &c. that require the strongest culinary Fire *a*).

V.

AXIOMS and CANONS, for the better Knowledge and Regulation of Fire.

We learn from the preceding Enquiry;

1. That the direct Senses afford but little Information as to the real Nature and essential Properties, or *Form of Fire b*).

2. That the *Form of Heat and Fire* is a certain bridled or restrained Motion, excited, maintained, and struggling in the minute Parts of Bodies, and tending to throw them off at the Surface *c*).

N. B. *If this Form be rightly discovered, then to introduce such a Motion, among the Parts of any*

a) If more be desired upon this extensive Subject, the Reader may consult the Lord Bacon, Dr. Hook, Mr. Boyle, Mr. Evelyn, Dr. Bohn, M. Homberg, Dr. Boerhaave, and Dr. Stahl.

b) See above, §. 3, 4, 5, 6, 7, 33.

c) See §. 7, 8, 9, 10, 11, 26, 27, 28, 29, 32, 33, 34.

Body,

Body will be to introduce Heat; or, if the Nature of the Body be capable of it, Ignition or Inflammation.

3. That as the direct inflammable Matter in all Fuel is the Fat or Oil it contains *a)*, the most oleaginous Fuel is the best or richest.

4. That Flame is the small Parts of an inflammable or considerably unctuous Body, actually set on fire, or briskly agitated and thrown off, with a certain vibrative Motion, at the Surface of that Body, into the open Air *b)*.

5. That Flame cannot exist without Oil *a)*. Whence it is that Ashes, Sand, Glass, Stones, and Earths do not flame upon Ignition, but rather damp and extinguish Flame.

6. That as Oil is the only inflammable Substance in nature *a)*, this may direct us to the means of preventing Conflagrations; *viz.* by using such Materials in Building as contain little or no Oil. This Direction might be likewise extended to the making of incombustible Paper for valuable Books and Manuscripts; new Materials for Hangings, Furniture, &c.

7. That as all Flame catches and exists only on the Surface of inflammable Bodies *c)*; we are hence led to invent Methods of casing, or otherwise defending, the Wood work of Ships and Buildings from Accidents by Fire.

8. That as the three capital kinds of Fire have a near relation, and may be very well reduced to one, for human Uses, *viz.* the culinary kind *d)*; Men may have reasonable Hopes of performing considerable things by its means in

a) See above, §. 22, 23, 24, 25, 33, 34.

b) See above, §. 26, 27, 29, 33, 34.

c) See above, §. 33, 34.

d) See above, §. 13--20, 34, 36, &c.

imitation of Nature; as particularly in promoting and regulating Vegetation, the Ripening of Ores, &c. by artificial Heats.

9. That Fire and Flame are abolished or extinguished by Suffocation, or an Action contrary to Ventilation *a*), as being destructive or preventive of that internal Commotion and Discharge of the oily Particles of the Fuel by means of the free Air, in which the nature of open and consuming Fire and Flame consists *b*). Hence Fire and Flame are quenched by Water, or even by Spirit of Wine or Oil of Turpentine, if a live Coal or lighted Candle be suddenly plunged therein below the Surface of the Liquor. For the Degree of Heat which Water, Spirit of Wine, or Oil of Turpentine unfired, are capable of receiving, being much less than that of a burning Coal or Candle, the greater Heat is subdued by the less; just as Fire is quenched by boiling Water.

10. That Heat is Fire in a less Degree, and Fire only a greater Degree of Heat, on which Lucidity, and, if the Matter be unctuous, Inflammability *b*), depend: as we see in hammering a Piece of Iron till it becomes red-hot; and in the firing of Wind-mills, or Coach-wheels, by their own violent Motion.

11. That Heat must aggregate and collect in a certain Proportion before it become cognizable to the Senses, or produce any manifest Effects of Fire or Flame. Thus a Degree of Heat below that of the natural human Body is insensible, or passes for a Degree of Coldness; and the ordinary Motion of Wind-mills, Carriages, &c.

a) See above, §. 26, 27, 29, 30, 31. See also *Axiom 2* foregoing.

b) See above, *Exp.* III, IV, V, and VI.

produces no remarkable Heat; tho' when the Motion is greatly increased, or the Friction considerable, it soon excites Fire and Flame *a*.)

12. That all the Chemical Operations require a certain or determinate Heat, in order to their being performed to the greatest Advantage; and that this Heat may be assigned and obtained, in every case, to the great Improvement of Chemistry *b*).

a) See above. §. 3, 4, 5, 6, 7.

b) See above, §. 44, 45.



LEC

LECTURE III.

CONTAINING

- (1.) *The general Properties,* (2.) *Ingredients,*
 (3.) *Nature,* (4.) *Office and Use of the*
Atmosphere.
- (5.) *The Changes therein;* (6.) *The Effects*
it produces on the Terrestrial Globe, and
 (7.) *In Chemical Operations.*

I.

*The Sub-
ject.*

1. **W**E are now to enquire into the Chemical Nature, Properties, Ingredients, Office and Use of the Atmosphere.

*The Atmo-
sphere,
what.*

2. By the *Atmosphere* we understand that whole Mass of rarefied Matter, or dry Fluid which surrounds the Globe of the Earth to a considerable Height.

*Its Import
to Che-
mistry.*

3. To discover the Nature, or the Influences and Effects of this Fluid, is of the utmost Importance to Chemistry; it being the general Fluid wherein all Animals, Vegetables, and Minerals grow, wherein our Fires burn, and every Chemical Vessel and Subject is included.

*To be ex-
amined in
three
States.*

4. We shall examine it as existing in three States, viz. (1.) As it is an intire Mass that surrounds the whole Terraqueous Globe; (2.) As it consists of dissimilar Parts, whilst it either lies open and remains one with the rest, or else is separated therefrom by being included in our Glasses or Vessels; and (3.) As it is united with, or fixed in Bodies. And from this Examination of the
 Parts

Parts of this general Fluid in different places we may infer the nature of the whole.

EXPERIMENT I.

That different Effluvia mix and form Clouds, or unite in the Atmosphere.

5. We unstopped a Bottle of strong Spirit of Sea-Salt, and another of volatile Spirit of Sal Ammoniac; and setting the Bottles near each other, the Vapours insensibly arising from them met, and formed themselves into a very gross visible Fume or actual Cloud, that continued for some time, but afterwards disappeared, or mixed more intimately with the Air of the Room. *That the Atmosphere receives Vapours.*

6. One of the Liquors here employed is an acid Spirit, and the other an alkaline one, which being mixed form a Species of neutral Salt or Sal Ammoniac. And as their Fumes are no other than fine Parts of the Liquors themselves, that still retain their Nature, they constitute this Kind of neutral Salt in the Air.

7. That something of the same kind naturally happens in the Atmosphere appears from hence, that all Vegetables produce a kind of volatile Salt by Putrefaction; that the volatile Salts of putrefying animal Substances, no less than the former, naturally go up into the Air, which contains likewise some Proportion of Sea-Salt raised from the Earth and Ocean: so that if these Particles meet they will necessarily make a kind of Ebullition, and unite into a neutral Substance, in the Atmosphere; which may hence abound with a variety of acid, alkaline, and neutral Salts, the Signs whereof are evidently discovered by the Changes they produce in the Colours of different Bodies.

8. This

8. This Experiment therefore may shew to the Eye somewhat of the physical manner wherein Clouds and Meteors are generated in the Atmosphere, and teach us that Salts naturally abound therein: whence again we have the physical Reason of many Effects produced by the atmospheric Air, in the animal, vegetable, and mineral Kingdoms, and in many Chemical Operations.

9. That the Atmosphere not only supports Vapours or Effluvia raised into it from the Earth, but also presses upon terrestrial Bodies by its Weight, appears from many Pneumatical Experiments; of which kind we need only produce two or three for the present.

EXPERIMENT II.

That the Atmosphere presses upon Bodies by its Weight.

The Pressure of the Air.

10. This was made sensible to the Hand applied close on the top of a hollow metallic Cylinder or Ring, about two Inches in Diameter, set upon the Air-Pump; for the Air being drawn out of the Cavity underneath, the Hand was remarkably pressed inwards, and felt a considerable Weight.

11. The Effect was likewise shewn in a different manner to the Eye, by the breaking of a piece of flat Glass applied close to the top of the same metallic Ring: for the Air being drawn away from below, the Glass was immediately crushed to pieces and fell inwards, with a loud Noise and a considerable Force.

The Air's Elasticity.

12. Besides this Weight or Pressure the Air or Atmosphere has likewise an elastic Force which is no less considerable; as appears by many Examples, and particularly by the following.

Ex-

EXPERIMENT III.

That Air is elastic, or capable of forcing, distending, or squeezing Bodies by its Spring.

13. We included a little Air in a Bladder, so as to leave it almost flaccid, and tying the Neck close put it into a Receiver, out of which we then exhausted the Air (but not out of the Bladder;) whereupon the Bladder immediately swelled and appeared as if full blown: but upon re-admitting the external Air the Bladder was presently squeez'd up, or contracted to its former Dimensions.

14. The second and third Experiment therefore shew that the Air or Atmosphere, both in its natural unconfined State, and when certain Portions thereof are included in Vessels, continually exercises a gravitating and an elastic Power, capable of producing many Effects; as continually pressing, by its Weight and Spring, all the Bodies we know. It perpetually presses upon the Surface of the Earth, with a Weight equal to that of a Column of Quicksilver whose Basis is that Surface, and whose Height is about 29 Inches; as manifestly appears by the Barometer.

15. Hence the Atmosphere will insinuate itself into the open Pores on the Surfaces of all Bodies, capable of receiving its component Particles. So that the Pores of many Substances, though to our Senses they appear Vacuities, are full of common Air; which thus produces the proper Effects of Air, in Distillations and many other chemical Operations.

16. The Atmosphere also, as a Fluid, must by the Laws of *Hydrostatics* press Bodies equally every way, and the internal Air of Bodies acting within, whilst the external Air acts without, numerous

merous physical Effects are hence produced in that great Laboratory, the Earth; where Bodies are by natural Powers and Agents dissolved, putrefied, changed, and carried off into that grand Repository the Air.

*The Effects
and com-
pounded
Nature of
the Atmo-
sphere.*

17. And tho' the Atmosphere itself be invisible, yet we cannot but be sensible of the Effects it produces, seeing they are by means of proper Contrivances and Observation, made perceptible even by the Senses, as in the preceding Experiments. And thus, tho' the Atmosphere be a rarefied and moveable Fluid, so that Bodies easily pass thro' it, yet broad Surfaces are greatly resisted by it. And hence its Force, as a resisting Fluid, becomes manifest in high Winds, by driving and dissipating the Clouds, and all kinds of Vapours and Exhalations; which are thus mixed in with the Mass of the Air, so as to form a heterogeneous Fluid, or Chaos of infinite Materials.

EXPERIMENT IV.

The Construction, Nature, and Use of the common Thermometer.

*Thermo-
meters ex-
plained.*

18. (1.) The common Thermometers are Glass-Tubes fill'd with tinged Spirit of Wine, and graduated, so as to shew, by the rising or falling of the Liquor, the Degrees of Heat to which it is exposed.

19. (2.) Spirit of Wine is chosen for this Purpose, because of all known Fluids it is the most rarefiable with Heat, next to the Atmosphere itself. Denser Fluids might be employed, but the Divisions would then be less; and Water is unfit for this Purpose, as freezing with Cold.

20. (3.) These Thermometers are the exactest Instruments hitherto known for measuring the Degrees of Heat; being filled either with Alcohol, Brandy,

Brandy, Oil, or Quicksilver, according to the several Purposes for which they are designed *a*).

21. (4.) The common Thermometer shews the Warmth of the Air; and that it always contains some Degree of Fire or Heat, more or less: for Spirit of Wine has never been found to freeze or congeal with any Weather, in any Climate; but rises and falls in the Tube as the Weather is more or less hot; with regard to which also the Atmosphere frequently varies.

EXPERIMENT V.

To determine the Proportion of Water contained in an assigned Portion of the Atmosphere.

22. Having, by means of the Air-Pump and an exact Pair of Scales, found the Weight of a certain Quantity of Air contained in a large Glass Vessel, we included therein a known Weight of well dried Potential Caustery (whose Property is powerfully to attract the Moisture of the Air;) and kept this Vessel close stopped for several Hours, during which time the Potential Caustery was grown wet: in this state we weighed it again and found a considerable Increase; which must be owing either to the Water attracted out of the Air in the Glass, or to a Condensation of the Air itself into an aqueous Fluid: for such a Fluid might now by Distillation be obtained from the Matter thus run *per deliquium* *b*).

23. There is some room to suspect that, if this Experiment were made in Perfection, a Weight of Water, almost equal to that of the Air included in the Vessel, might be thus obtained; which would prove a very extraordinary Discovery, and

a) See *Let. II. §. 46.*

b) The Experiment was not made with all the requisite Exactness.

shew

shew what some have endeavoured to prove, that the Matter of common Air is little more than Water *a*).

24. That much Water must needs be contained in the Air appears evident from the Quantity daily exhaled by the Sun, from the Ocean, the Rivers, and the whole animal, vegetable, and mineral Kingdoms. And as the Water so raised into the Atmosphere must necessarily mix and join with the saline and other Particles it there meets with, and is capable of dissolving; hence the Water of all our Springs, Rivers, and the Ocean itself is impregnated with numberless Matters, that little appear in Water. And possibly to give the animating or vivifying Spirit to Water, it is physically necessary that it should be perpetually refined or refreshed by this Kind of Distillation, or recruited and new impregnated with the Effluvia or fine Particles of all the Bodies floating in the Atmosphere; after the same Manner as a skilful Operator, to give his distilled Waters the finer Impregnation, suspends a proper Mixture of Ingredients in the Head of his Still.

EXPERIMENT VI.

That a Refreshment or Renewal of Air is necessary to Life.

*Fresh Air
required
in Respi-
ration.*

25. If Animals or Plants be long continued in the same close, unchanged, or unrefreshed Air, they will languish and expire, much after the same manner as Fire would do, by a Kind of Suffocation *b*).

26. Hence it appears that the Air, which has once served for the Respiration either of an Animal or Vegetable, is unfitted for the same Office

a) See the Lord Bacon's Natural History of Winds, *passim*.

b) See *Lea*. II. §. 29. & *alibi passim*.

again,

again, till it be recruited, as it seems to be, by mixing with the open atmospherical Air. Every Man is computed thus to despoil a Gallon of Air in a Minute; whence, if the Number of Animals and Vegetables on Earth be consider'd, it should seem that the whole Atmosphere must in time be despoiled, unless some natural means were used to prevent it. Indeed, on weighing the matter attentively, one might suspect that the Particles of numberless Materials, fermenting * together in the Atmosphere, produce a certain *Spirit*, or fine vivifying Substance, that thus renovates and invigorates the whole Mass, and renders it again fit for Respiration and the Sustainment of all natural Bodies. And hence perhaps it is that no ill Effects are usually felt from that immense Quantity of gross Smoak continually discharged into the Atmospheres of large Cities. All Bodies suffer a kind of Transmutation, and may, by the established Course of Nature, go the same rounds again. And hence also it is no wonder that Air, when so richly impregnated with Water, Soot, Smoak, Salts, Oils, Kitchen-Exhalations, &c. should prove in some degree nutritive.

EXPERIMENT VII.

That loose Air is contained in Fluids.

27. We put Water, Small-Beer, and Brandy *Air in li-*
severally into an Air-Pump Receiver, and ex-^{quots.}hausting the Air observed numerous Bubbles to arise and escape from each Liquor, bursting upon its Surface.

28. And in like manner is Air discharged from Liquors by boiling them over the Fire: This is practised upon Water, in order to make

* See Lect. VII. *passim*.

LECTURE THE THIRD.

it afford Ice without Blebs or Bubbles; and again upon Oil designed for *Thermometers*, &c. But such Liquors as have been thus discharged of their loose Air, will be found to recover it again by standing open; as if loose Air were a natural Ingredient in Liquor.

EXPERIMENT VIII.

That the external Air may promote Solution.

29. We set some Spirit of Sal Ammoniac and Copper-Filings *in vacuo*, and compared this with a like Parcel standing for the same time in the open Air: that *in vacuo* had not coloured its Menstruum, whilst that in the open Air afforded a rich blue Tincture. Hence it appears that the free Access of the external Air may promote Solution in some Cases; where it seems to act by increasing the Motion or Action of the Menstruum.

EXPERIMENT IX.

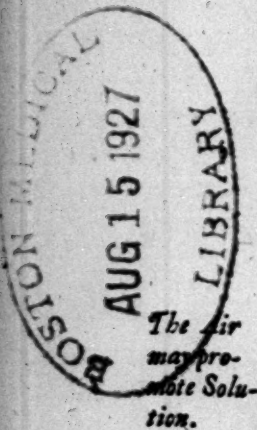
That the external Air does not promote Solution in all Cases.

Yet in some Cases only. 30. Upon two Drams of whole Crab's Eyes we poured *in vacuo* two Ounces of distilled Vinegar, having first boiled it to get out the Air. A great Ebullition was immediately produced, the Gage sunk, and Air was generated.

31. Upon comparing this with the same Experiment made in the open Air, we found that the Ebullition was much greater *in vacuo* than in the open Air.

32. Hence we learn that Air may be generated upon the mixture of certain Bodies, where it did not appear before.

33. But



33. But Experiments of this Kind must be made with Caution; the Quantity of Air thus generated in some Cases being able to raise the Receiver, and throw it to a considerable Distance.

34. There is wanting an Account of all the Mixtures that will produce Air in so violent a Degree; among them may be reckon'd Oil of Vitriol with Oil of Tartar per deliquium, Aqua Fortis with Iron Filings, Spirit of Nitre with Oil of Caraway, &c.

35. And thus Air may be generated betwixt Solids and Fluids, and betwixt Fluids and Fluids, by bare Mixture. The following Experiment will shew that Air may be extricated out of Solids, and that it makes a constituent Part thereof.

EXPERIMENT X.

That Air enters the Composition of Solid Bodies.

36. We put a Piece of hard Tallow into an Iron ^{Air in So-} Retort with a long Neck; then laying the large ^{lids.} End of the Retort in a naked Fire, the small one being plunged into Water, we distilled in the usual Manner, and observed that large Bubbles of Air continually rose and discharged themselves thro' the Water into the Air of the Room. At length ceasing the Operation, and collecting all the visible Matter either left behind or come over into the Water, we found a very considerable Loss of Weight, owing to the Air having been separated or forced by the strong Heat from the rest of the Tallow *.

37. If it be objected that the Loss of Weight might, in great Measure, be owing to the Iron of the Retort, which when hot has the Property of drinking in Oil or Tallow; it may be obser-

* The Experiment was not made with requisite Care and Caution.

ved (1) That the Effect is nearly the same when an Iron Retort is employed that has been used for the same Operation before; (2) That the Experiment answers proportionably when made in Glafs; (3) That other Bodies besides Tallow, particularly Hartshorn, Bone, Tartar, &c. yield plenty of Air, when treated in the same manner; (4) As there is so large a Quantity of Air-Bubbles discharged in the Operation, and as Air is proved to be a ponderous Body *a*), the Loss of Weight may be fairly attributed to the escape of the Air. But (5) a proper Gage may be contrived to determine the exact Proportion of the Air thus separated, with respect to the original Matter or Subject employed *b*).

38. This Experiment is of great Importance in Natural Philosophy and Chemistry. When fully verified and duly prosecuted it may shew (1) that all natural Bodies consist of a very large Proportion of Air, as one Part of their original Composition; (2) That Air is necessarily required to the Formation and Growth of Animals, Vegetables and Minerals; (3) That when Bodies are dissolved or resolved a great Part of them turns into Air again; as when a Candle is burnt or Fuel consumed; or as when Vegetables, Animals and Minerals ferment, putrefy or corrupt; or as when Bodies are chemically analysed or treated by Heat.

39. (4) That the Matter which in the Distillation of Hartshorn, Tartar, and many other things explodes and puffs thro' the Luting, or sometimes, when confin'd, bursts the Glasses or Vessels, is the Air set free by the Heat.

a) See above, *Exp. II.*

b) See Mr. Hales's *Vegetable Statics*, under the Analysis of the Air.

40. (5) That the Air thus naturally condensed, confined, and intermix'd as a constituent Part in Bodies, has a great Share in their Dissolution ; for being violently rarified it breaks the parts in pieces and flies off.

41. (6) But leaving the Experiment to be further verified, and made general, if capable thereof, we shall anticipate no more, but proceed to reap the Fruits of the present Enquiry.

II

AXIOMS and CANONS derived from the Enquiry.

1. We learn from the preceding Enquiry that the Atmosphere, considered as a Whole, and again as consisting of an infinite Number of Ingredients, is the Physical Cause of numerous Effects, not only in the Air itself, but likewise upon the Surface of the Earth, in the subterraneous Regions, in the Exercise of numerous Arts, and particularly in Chemical Operations *a*).

2. That it is the physical Office and Use of the Atmosphere to assist in raising the Vapours and Exhalations of the Earth *b*), and to serve as a general Matrix for them *c*), wherein they are all blended together and fermented, or some way changed in their Nature, so as to perform new Offices, or recruit the vegetable, animal, and mineral Kingdoms, when such enriched Vapours fall back again in Rain or Dew to the Earth *d*).

3. That it is the Nature of Air to insinuate itself into Fluids *e*), unite and fix in Solids, so as

a) See above, *Exp.* II. III. IV. V. VI. VII. VIII. IX. X.

b) See *Exp.* I.

c) See *Lect.* I §. 16.

d) See §. 25, 26. & *alibi passim*.

e) §. 27, 28.

naturally to make a constituent Part of both *a*).

4. Hence may be conceived, in general, how all the Changes happen in this great Chaos the Atmosphere; viz. according as floating Particles of different Kinds chance to meet, so as to form considerable Aggregates or Collections; and according as these are favoured by the requisite Degrees of Heat, Cold, Dryness or Moisture. So, for example, a Cloud of nitrous Spirit meeting with a Cloud of oily Particles might suddenly produce Coruscations, as in the mixing of Spirit of Nitre and an essential Oil *b*). And in this manner may the Generation and Phænomena of all the Meteors be chemically explained. And thus the Occurrences of various Parts of different Bodies in the Atmosphere may be the Cause of the Meteors, fiery Winds, Explosions, Thunder, Lightning, the Aurora Borealis, and other Phænomena, which we can imitate by certain Mixtures, in the way of Philosophical Chemistry *c*).

5. That the Atmosphere is an universal Instrument, in the Hands both of Nature and of Art, for producing Effects, whether on the Surface of the Globe, in the Bowels of the Earth, in the Air itself, in the Laboratory, or in other human Works *d*). Thus it causes Fire to burn, and Bellows are but Engines to convey it thereto.

6. That as Air descends, and acts more forcibly in the subterraneous Regions, on Account both of its greater Density there, and of the subterraneous

a) §. 27, 28, 36, 37, 38.

b) See *Exp. I.*

c) See Mr. *Lemery's* Philosophical and Chemical Explanation of Subterraneous Fires, Earthquakes, Hurricanes, Thunder and Lightning, in the *French Memoirs*, Anno 1700.

d) See the whole *Lecture passim*. See also *Lect. I. passim*.

Heat; hence Vulcanos and more violent Fires may happen there than upon the Earth's Surface *a)*. And possibly this greater Heat and Power of the Air below is necessary to the Production of Minerals and Metals *b)*.

7. Hence we may learn the physical Cause why in the open Air distilled aromack Oils lose their native Spirit, grow thick, and terebinthinate; why Wines grow flat or lose their Briskness; why pale volatile urinous Spirits grow red; why Mineral Waters lose their Virtue; and how Air has in all respects a powerful Influence upon Liquors; as being a dry Fluid in brisk Motion, whereby it easily lays hold of and carries off all the most subtile and volatile Parts of Fluids, leaving the grosser behind, and thus changes the Texture, Colour, and Consistence thereof *c)*.

8. That the Atmosphere is, perhaps, the most compounded and dissimilar Mass in Nature; consisting of an elastic Part, and the Vapours and Exhalations arising from all the solid and fluid Bodies of the Globe, Salts, Oils, Minerals, Metals, &c. *d)*.

9. That the Air is the Cause of numerous Effects, ill ascribed to other Causes by the ancient Chemists, who for want of the Air-Pump and other Contrivances, were ignorant of the genuine Properties and Effects of the Air *e)*.

10. That the component Parts of the Atmosphere are coarser than those of Fire. For the

a) See *Lect. II.*

b) See above, *Exp. X.* See also the *Lecture* on Metallurgy hereafter.

c) See *Exp. I. VI. IX. & §. 18.*

d) See *Exp. I. &c.*

e) See *Exp. VIII. IX. X.*

component Parts of the Atmosphere will not pass thro' Glafs *a)*, Stones, Metals, &c. as Fire does. Also Water, Lixiviums, Oils, &c. pass where Air cannot; as we see in Bladders, Wet-Leather of the Air-Pump, &c. Hence the Air may be artificially excluded from many Bodies. *b)*.

11. That the Atmosphere is continually at work upon all the Bodies Subject to its Power, in the way of a Menstruum; whence Iron standing in the open Air is corroded; imperfect Glafs, dissolved; Salts and Sugars run into Liquor; and the Bodies of Animals, Vegetables and Minerals prey'd upon *c)*.

12. That there is a continual Reciprocation betwixt the Earth and the Atmosphere; they mutually distilling, as it were, or throwing off Matters from one into the other. Thus the Earth, by the Sun's Heat, sublimes some Parts of all things into the Atmosphere, and the Atmosphere again precipitates them to the Earth *d)*.

13. That the different Success of Chemical Operations may be greatly owing to the particular Vapours or Effluvia floating in the Laboratory where such Operations are performed *e)*, Thus if Salt of Tartar be run *per deliquium*, where Vinegar is distilling, it becomes regenerated Tartar; a thing very different from the intended Oil.

14. As Air always adheres to the Surfaces of Bodies, and as the Surfaces of Bodies are enlarged by pulverizing them *f)*; when we would exclude

a) See Exp. II. III. VII. VIII. IX.

b) See Exp. II. III. VII. VIII. IX.

c) See Exp. I. II. V. VI. VII. VIII. IX. See also below, Ax. 20.

d) See Exp. I. & Lett. I. *passim*.

e) See Exp. I.

f) See Exp. II.

Air in Chemical Operations, the Subject should not be pulverized.

15. That the open Air has a powerful Efficacy in many Chemical Operations, especially in Mixture *a*), where it often acts mechanically by its Weight and Motion; as in the mixing of Oil of Turpentine with Salt of Tartar, which does not succeed *in vacuo*, or in high mountainous Places.

16. That the Access of Air is not necessary to certain Fermentations, or Ebullitions, and Solutions; some of them proving more violent *in vacuo*, than in the open Air *b*).

17. That no Degree of Cold, or Condensation, has hitherto been able to deprive Air of its Fluidity, or render it consistent *c*). If there were such a Power exerted in Nature, it would destroy all Animals and Vegetables, and perhaps stop the Growth of Minerals *d*).

18. By comparing the present Enquiry with the preceding, it appears that Fire cannot separate Oil from Bodies, without the Admission of the free Air. Whence in the roasting of sulphureous Ores, or obtaining of white Ashes from Bones or Vegetables, we are directed to use an open Air, as well as a naked Fire.

19. That the Air is in a Kind of perpetual Motion *e*). Whence it performs all those natural Offices, that cannot be performed in a *Vacuum*. Thus leaven'd Paste will not ferment or rise, nor Wine work, nor Flesh putrefy, nor Fruit corrupt, after the usual manner, when placed *in vacuo*.

a) See Exp. VIII.

b) See Exp. IX.

c) See Exp. IV.

d) See Exp. VI. & X.

e) See Exp. I. & IV. See also Ax. 12. & 17.

20. That

20. That as all kinds of Particles naturally float in the Air *a)*, the Air may on this Account act as an universal Menstruum, and in time dissolve any Body exposed to its Action; because, in tract of Time, the Particles capable of dissolving it must necessarily come at it *b)*.

21. That many Arts may be assisted, or carried on to better Advantage in some places than in others, by the means of certain Particles floating in the Air of one Place more than another. Thus 'tis said that the Scarlet Dye is better struck at *Leyden*, than in other Places of *Holland*, where the Water and Atmosphere are not so impregnated with the Effluvia, Exhalations, or fine Particles of the Dye *c)*.

22. Hence also we are directed to chuse proper Seats for Health, and Habitation, as well as for Operations and the Exercise of Arts *d)*.

a) See *Exp. I. & alibi passim.*

b) See *Ax. II.*

c) See *Exp. I. & alibi passim.*

d) There are various Methods of trying the Wholesomeness or Unwholesomeness of Airs and Places; as by finding their Degree of Moisture several ways; by the Changes of Colour produced in white Linen, or stained Paper, left out in the Air; by exposing Copper-Plates to shew the Colour of the Vitriol thereby made; and many other Expedients might be contriv'd for that Purpose. [See Mr. *Boyle's* Natural History of the Air.]

LECTURE IV.

CONTAINING

The Solid or Earthy Matters of the Terrestrial Globe classed, and examined, under (1.) Garden Earths; (2.) Bolar Earths; (3.) Saline Earths; (4.) Sulphureous Earths; (5.) Stony Earths; and, (6.) Metallic Earths.

1. **W**E now come to enquire into the solid *The Sub.* or earthy Contents of the Globe; *ject.* more particularly into the Parts concerned in Vegetation.

2. We shall begin with the Earth's Surface, and descend down gradually, so far as Men have hitherto dug.

3. The Earth's Surface is generally found covered with Verdure, or a Vegetable Coat, and *The Upper Coat of the Earth.* in some Places with Sand, Dust, or Mud.

4. Under this superficial Coat there usually lies a Bed of Mould, or Underturf-Earth, of different Depths, from one Foot to two, three, or more, in different Places. (1.) This Mould, or Underturf-Earth, is the proper Matrik of Vegetables, and will come to be first examined in Order.

5. We shall next proceed to the other Species *The Species of Earths.* of Earths that lie below, viz. (2.) the Bolar; (3.) the Saline; (4.) the Sulphureous; (5.) the Stony; and (6.) the Metallic. For under these
fix

six general Classes, we apprehend, may all the earthy or solid Matters of the Globe be ranged.

6. It will therefore be our Endeavour to give a general Example of the Method of treating every Species, so as to discover their Natures, Offices, and Uses.

EXPERIMENT I.

The farther Analysis of Garden-Mould or Underturf-Earth by Water a).

Mould analysed by Water.

7. (1.) We took four Pounds of fresh, black and crumbly Garden-Mould, that was esteemed the best sort, and had lain, for a Year. exposed to the Atmosphere, without being exhausted in Vegetation.

(2.) This Mould we elixated in fair and fresh boiling Water, till all that was capable of dissolving therein was got out or extracted by the Water.

(3.) Having thus obtained a Lixivium or Solution of our Subject, we filtered it thro' thick doubled Paper, in order to have it transparent, and at least free from any gross terrestrial Parts, that might otherwise lodge therein.

(4.) This Solution, therefore, contains all the Parts of the Subject that are soluble in boiling Water *b*).

(5.) To bring these Parts nearer together, that they might manifest themselves to the Senses, and particularly to the Taste, we exhaled away the more aqueous Fluid in the Form of Vapour.

(6.) Then comparing the concentrated Solution, with a Portion of the former that re-

a) See Lett. I. Exp. I.

b) See Lett. I. Exp. I.

mained unevaporated, we found it taste manifestly stronger or more saline.

(7.) To gain a fuller Information, we evaporated a Portion still higher, and set it to crystallize, if any Salt would shoot *a*).

(8.) To a Part of the filtered Solution we added Syrup of Violets, &c. to discover whether the Solution was acid, alkaline, or neutral; and found it rather the latter *b*).

(9.) We washed the remaining terrestrial Matter in several Waters, every time decanting the upper muddy Liquor, after a little standing, in order to procure the pure Sand contained in the Mould; and found the Sand to be a large Proportion of the whole.

8. This Experiment, or rather Combination of Experiments, shews us a Method of resolving the matrix Earth of Vegetables into the constituent Parts thereof, without altering their natural Form and Properties. Whence it should seem that a true Judgment might be formed of Moulds, both in general and particular, so far as this Information reaches, and a Rule be obtained for their artificial Mixture or Composition. Thus we find the Mould under Examination contains a certain Proportion of fine Earth, capable of being suspended in Water; much more of a grosser heavier Part that readily sinks in Water; perhaps a little neutral Salt; and a large Proportion of Sand. Hence if this Mould had come from the Island *Ceylon*, for instance, having there served for the Growth of Cinamon, we might be directed by this Analysis to make or mix up a Mould that should resemble it, with a View to produce Cinamon

a) The Success was not carefully noted.

b) See the Method of examining *Mineral Waters*, in the following *LeBure*.

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in *England*. But to make the Experiment successful, no less Regard must be had to the State and Ingredients of the Atmosphere, than to the State and Ingredients of the Soil *a*).

9. To render the present Experiment more instructive and useful, for discovering the Principle of Vegetation, and the Nature of Earths and Plants, it were proper to compare it with a similar Analysis of certain vegetable Subjects. Thus by bruising a tender Plant, elixating all its soluble Parts with warm Water, exhaling the superfluous Moisture, and setting the Remainder to crystallize, we obtain the native saline part of the Plant, in the form of a solid Salt, which appears either of the tartareous or nitrous kind, according to the Nature of the Plant *b*).

10. Tho' any alkaline Plant, as Cresses, were watered in its Growth with a Solution of Nitre, which upon Distillation affords much acid Spirit, the Plant would still prove alkaline: and the same holds of every Plant and Salt hitherto tried *c*). Whence there appears to be in Plants a Power of changing any other Salt into their own. And hence we find, upon Experience, that Composts abounding in Sea-Salt, Nitre, or urinous Salts, all agree to promote Vegetation.

11. But as there may be certain more fixed Parts naturally contained in Mould, than will dissolve in boiling Water; and as these Parts may possibly be loosened, digested, and rendered capable of ascending into Vegetables, by the

a) See *Lect. III.*

b) See *M. Homburg* on the Nature of Vegetable Salts. *Memoir, de l'Acad. An. 1699.*

c) I could wish the Experiment were tried with Sugar, Alum, Pot-Ash, &c. both in Alkaline and acid Vegetables. But Care should be taken not to use too much of the Salts, which in that Case would destroy the Nature of the Mould.

long-continued Action of the Sun and Atmosphere; it may be proper to try a more powerful Analysis of the same Subject.

EXPERIMENT II.

The Analysis of Garden Mould by Fire.

12. Having weighed two Pounds of the same *By Fire*. kind of Virgin-Mould as was used in the preceding Experiment, we put it into an earthen Retort, and committed it to a naked Fire, working by slow Degrees of Heat into a Glass-Receiver; and at last keeping the Retort ignited for some time. There came over (1.) a Water; (2.) an Oil; and (3.) a volatile Spirit almost like Spirit of Hartshorn, or as if the Subject had been animal*; and (4.) there remained behind a dry *Caput mortuum*, or apparently fixed and inert Earth.

13. We elixated Part of the *Caput mortuum*, and then dried it; by Triture we reduced another Part into one similar, homogeneous Powder; with a design to put each Parcel into a separate Pot, and expose them to the open Air, for a Year, to try whether they would then prove fertile.

14. It appears by this Experiment, that our Garden-Mould was of a Vegetable or Animal Nature, in respect of the Salts or Juices it contained; and only Mineral, with regard to its fixed Matter. In both which respects it greatly resembles the natural Composition of Animals and Vegetables. And hence we see the physical Reason, why animal and vegetable Substances

* If it be supposed, that the Compost, which might have been used to this Mould, was not sufficiently rotted or changed, so as still to retain its own vegetable or animal Nature; let the Experiment be repeated with Earth, which has been known to have lain several Years fallow.

are proper Composts for Land. If we were to enquire how Mould comes to be of this Nature, it might in good Measure appear from our former Doctrine of the natural Contents of the Atmosphere; which being animal and vegetable, as well as mineral, continually fall upon the Surface of the Earth. And hence Gardeners find a manifest Difference between the Soil of *London* and that of open Country Places, on Account of the Quantity of Smoke daily precipitated out of the Air upon the Gardens of *London*. And the like is to be understood of other Cities and Countries respectively.

15. By comparing the present Process with the same performed upon a vegetable, an animal, and a mineral Substance; it appears that one simple *fixed Earth* is the Basis of all animal, vegetable, mineral, and earthy Matters; or the true *Stamen*, Support, and Skeleton of Flesh, Bone, Wood, Metals, and Earths, &c. being in itself of a fixed unalterable Nature.

16. We next proceed to *Bolar Earths*, which seem divisible into two Species, according as they are more or less tenacious; in which view *Loam* and *Clay* may represent them all. And even these two seem only to differ in respect of the Fineness or Coarseness of their component Parts, which renders them more or less tenacious, clinging, or adhesive.

EXPERIMENT III.

That Fineness of Parts in Earths may give Cohesion, Strength, and Solidity.

*Loam
made into
Clay.*

17. (1.) We mixed common Loam into a Mass with Water, and then dry'd it; to shew that, compared with Clay, it would easily break, crumble, and fall into Powder. But (2.) beating some

some Loam fine in a Mortar, and mixing it well with Water, it clung like Clay; and when dry'd, adhered much more tenaciously than before.

18. This Experiment not only shews that Loam and Clay, or all the Bolar Earths, are nearly the same thing, when their component Parts, or gravelly and sandy Matters, are reduced to the same Degree of Fineness; but also supplies us with a Rule for the Improvement of Pottery, and the Imitation of *China* Ware. This Rule is to grind, or beat, the Earths employed, to an extreme Degree of Fineness: and accordingly Porcellane has been imitated in *Europe*, by Tobacco-Pipe Clay and other Earths exceedingly fine ground, mixed into a Paste with Water, and properly dried or baked. *Pottery hence im-
proveable.*

19. The same Experiment may likewise in- form us how Rocks are often produced, of different Degrees of Hardness, according to the different Fineness of the terrestrial Particles deposited upon any Eminence, or Declivity, as washed down by the Waters. *Farther
Uses of the
Experi-
ment.*

20. We recommend it to future Examination how far this mechanical Tenuity of Parts may reach, in causing Strength and Hardness in Bodies: and whether those two Properties are not different in Glass, Crystal, Diamonds, &c. on Account of the different Fineness of their Parts. *

21. Under this Tribe of Bolar Earths we rank all the hungry Garden-Earths, all the sandy Field-Earths, all the Clay or Marly Earths, and all the Mixtures thereof. *Bolar
Earths
what.*

22. We next proceed to Saline Earths; by which are meant all those wherein any Quantity of Acid, Alkaline, or Neutral Salt is evidently contained. *Saline
Earths.*

* See Mr. Boyle on Gems.

23. If strict Examination were made, perhaps no Earth would be found without some Proportion of Salt; which has pretty generally been thought the Principle that holds all Earths together. And there appears some Reason for the Opinion, as we endeavoured to shew by the following Experiment.

EXPERIMENT IV.

That a Saline Matter may give Tenacity and Firmness to Earth.

Quick-lime deprived of its Salt.

24. (1.) We slaked Quick-lime with a sufficient Quantity of Water to bring it into a Kind of Paste; (2.) Then suffered the superfluous Moisture to exhale gradually: Upon which, (3.) the Lime acquired a stony Hardness. (4.) We next poured a much larger Quantity of Water upon another Parcel of Quick-lime, than sufficed to make it into a Paste; then decanted the Water, which tasted manifestly saline. (5.) We afterwards elixated the remaining Matter with several Parcels of fresh Water, to get out all the Salt of the Lime; (6.) And now drying the Calx thus deprived of its Salt, we found it would not hold firmly together, but remained quite crumbly or dusty.

Uses of the Experiment.

25. This Experiment shews us the Nature and Composition of Lime, which, mixed with Sand, makes the common Mortar used in Building. We see it is the Alkaline Salt contained in the Lime, and either extricated or produced in calcining the Lime-stone, that occasions the Mortar to concrete and harden, And where the Salt is in its full Proportion, the Lime is strongest, and the Mortar hardest and most durable. This saline Principle in Lime is also that which gives it the Advantage over Chalk, as a Compost for Grounds,

Grounds exhausted or drained of their natural Salt in Vegetation. For the Alkaline Salt of the Lime, by strongly attracting the Moisture of the Atmosphere, and other Particles that float therein, swells, dilates, crumbles, and opens the Earth with which it is mixed; whence the Atmosphere has the freer Action thereon, and in the mean Time the Alkaline Salt of the Lime becomes of a neutral, or nitrous fertilizing Nature.

26. Under the general Head of Saline Earths may be reckoned all those that are calcined or burnt in the Fire; as all the Kinds of Lime, Potash, Salt of Tartar, Soot, &c. these being but Mixtures of Salt and Earth: and to say the Truth, all Salts appear upon a rigorous Examination to be no other than Earths of different Natures; which, when reduced to a certain Degree of Subtility or Fineness of Parts, so as permanently to dissolve in Water, are then emphatically denominated Salts.

*The Class
of Saline
Earths.*

27. The following Experiment regards the Sulphureous Earths, under which we reckon all those that will flame in the Fire; as Coal, Bitumen, Sulphur, certain crude Ores, Marcasites, &c.

*Sulphu-
reous
Earth.*

28. By Marcasites we understand all those Mineral, Earthy and Sulphureous Matters, that are otherwise called *Pyrites*, Fire Stones, Brass-lumps, Mundicks, or the like. For tho' these may be distinguished in respect of lesser Differences, yet in general they are all a Composition of Sulphur, un-inflammable Earth, and a small Proportion of Metal.

*Marcasites
what.*

EXPERIMENT V.

The Analysis of sulphureous Earths by an Example in Mundick.

*Mundick
analysed.*

29. We took half a Pound of Mundick reduced to fine Powder, and put it into an earthen Retort, which being placed in a naked Fire, we fitted on a capacious Glass-Receiver, and luteing the Juncture well with a Mixture of Loam and Horse-dung, we gave Degrees of Fire up to the strongest; then letting all cool and taking off, we found a small Proportion of an acid Liquor, exactly like the Spirit of Sulphur, made by the Bell, at the Bottom of the Receiver, and a considerable Quantity of Flowers of Sulphur sublimed to the Top.

30. The *Caput mortuum* being taken out, and flux'd with half its Weight of clean Iron Filings, afforded a little Lump of a Metallic Substance, or *Regulus*.

*Uses of the
Experiment.*

31. Hence we see that Marcasites chiefly resolve into Sulphur, and a more fixed earthy Part, which being treated as an Ore yields a Proportion of Metal. And hence perhaps all the Pyrites, Brass-Lumps, Marcasites and Mundicks are but cruder Kinds of Ore, and if they could be brought to full Maturity, would prove real Ores.

*Marcasites
fring.*

32. These Marcasites, upon long lying in the open Air, attract the Moisture thereof, thence grow hot, in some Measure dissolve, form an Efflorescence on their Surface, and by Degrees turn into a Vitriol, of the same Kind with the Metal they contain. Thus if that Metal were Iron, the Vitriol becomes green or martial; if Copper, blue or cupreous. And on this is founded

founded the Artificial Method of making Vitriol, now practised in several Parts of *England*.

33. And from the heating, fuming, and firing of these Sulphureous Earths, by the Moisture of the Air, we may perhaps learn the Origin of Hot Baths, Mineral Waters, Damps and Fires in Mines. For it is found, that a Pile of these Sulphureous Earths, being barely moistened, will at first smoke, and at length take Fire, and burn like glowing Coals *a*). *Whence Hot Baths, Damps and Fires in Mines, &c.*

34. Our present Experiment likewise shews us a Way of examining these Marcasites, and of extracting the Metal they may hold, after having first separated their Sulphur. Many skilful Metallists have been imposed upon by the specious Shew of these Marcasites; for they usually have a great specific Gravity, and some of them a greater than real Ores: whence again they may possibly contain the Matter of Metals, tho' in a crude, imperfect, or unfixed State. But to bring this Matter to the Test, and to try the Validity thereof, requires more than a common Knowledge in Metallurgy *b*). *How examined for their Metal.*

Our next Species of Earths is the Stony.

Stony Earths.

EXPERIMENT VI.

That Ignition may destroy the Tenacity or Cohesion of Stony Earths, shewn in Alabaster.

35. (1.) We reduced two Pounds of Alabaster to fine Powder; then put it into a flat Iron Pan, *Alabaster calcin'd.*

a) See Dr. Power's Experiments, page 63.

b) A small Proportion of Silver has been obtained from certain Kinds of Mundick, after the Mundick had been fluxed with Iron Filings, and brought to a Regulus.

and apply'd a soft Heat, that the Matter might not glow, yet remain too hot to be touch'd. The Powder was thus brought to flow or run like Quicksilver, and being gently stirred, to boil and bubble. We let it continue thus, with a soft Heat, till it would run off a Spatula held almost horizontal; then removing it from the Fire, it grew cold, and was put into a Glass, kept close stopp'd and set in a dry Place, under the Name of *Gypsum*, or calcin'd Alabaster.

(2.) A Parcel of the *Gypsum* thus prepared being brought into a pappy Consistence with Water, the humid Mass became so hard and rigid, in a Quarter of an Hour, as to ring, or afford a clear Sound, when struck with the Finger, or any more solid Instrument.

(3.) But a Parcel of the same Powder being kept in a State of Ignition for some time, before it was taken out of the calcining Pan, and then mixed with Water, acquired only a loose, friable Consistence, or a much less Degree of Hardness and Tenacity than the other. The un-ignited Sort also, by being kept in the open Air, loses of its coagulating Virtue; and when once consolidated with Water, becomes unfit for the like Purpose again.

*Uses of the
Experiment.*

36. Thus all the Stony Earths that do not vitrify in the Fire, are by Ignition reduced to fine Powder. So may Flints themselves, by being often ignited and quenched in Water. And thus white Marble or Crystal is reduced to a Powder, fit for the making of pure white Glass.

37. This Experiment also shews us an earthy Matter, apparently fluid over the Fire, that will harden in Water, and serves to direct a farther Enquiry after cheap Bodies, that will grow still harder under Water; which might be of Service

Service in Bridge-works, Water-works, and the like *a*).

38. The present Use of the Preparation is sufficiently known, for taking off Faces, Impressions and Figures, and the stopping of leaky Pipes, or Vessels that transmit or contain Water.

39. The sixth Class is that of *Metallic Earths*: *Metallic Earths.* For there are some Reasons to judge, that even Metals themselves are but a Species of Earths *b*), as they both burn into Ashes, and melt into Glass; whilst their metallic ductile Form seems owing to nothing more than a certain Proportion of Sulphur or Oil contained in them; which being burnt out, leaves them terrestrial Calces, or certain Metallic Earths, of a nature peculiar to each Metal *c*).

40. And thus we may divide Earths into two *Earths reduced to two general Kinds.* general Tribes, viz. the *Brittle* or *Friable*, and the *Ductile* or *Malleable*. We have gone thro' the Friable Species; and shall prosecute the Ductile hereafter, in our Lectures upon *Mineralogy* and *Metallurgy*.

AXIOMS and CANONS.

I. We learn from the foregoing Enquiries, that the Atmosphere, with its Contents, is a chief Instrument in promoting the Fertilization of the Earth, whereby all Vegetables, and thence all Animals are fed, supported and maintained *d*); that this Mould may in some Measure be sup-

a) See Mr. Boyle's Philosophical Works, Abridg. Vol. I. pag. 330, 331.

b) See Becher's *Physica subterranea* passim.

c) See Stahl's Comment. on Becher's *Physica subterranea*; & alibi passim.

d) See *Leç. III. passim*. See also the present *Leç. Exp. I. II.*

plied by the Air, at different times *a)*, and afterwards by lying immediately under the Turf, receive whatever Richness or fine Matter descends from above, in the Form of Dews, Rains, Snow, Hail, or other more subtile Conveyance; and that this invigorating Substance soaking thro' the upper Turf, may be thereby defended from the Winds and beating Sun, as by a Skreen, from being exhaled too soon again. And thus the Atmosphere exercises a Kind of renovating Power, so as to supply even exhausted Earths with fresh Vigour, and fit them for the Production of new Crops *b)*. Whence we have a good Rule for renovating and recruiting shrunk, withered, and exhausted Vegetables, by exposing them to a kindly Atmosphere, rather than by barely watering them; which might only serve to corrupt and spoil them the sooner.

2. That some capital Rules may be formed for the Improvement of Agriculture, Horticulture, and the raising and improving of Fruit and Forest Trees, by finding the Nature, Composition, and Ingredients of the Soil wherein each Kind of Grain, Plant and Tree, is most delighted *c)*.

3. That it is possible, by rational Experiments, to find the best Kinds of Steepings for Grain and Seed, and the best Kinds of Composts and Manure for Land according to the Nature or present Exigence of the Soil, or the Fruit intended to be produced; or any one particular Salt, Oil, or Property to be introduced, either into the Ground or Seed *c)*.

a) See *Leß. III.*

b) See *Leß. III.* and the present, under *Exp. I. & II.*

c) See *Exp. I & II.*

4. That

4. That Water, as well as Fire, may be an useful Chemical Analyser in some Cases *a*).

5. That all vegetable and animal Substances, Excrements, &c. naturally change and become Compost, and at length Mould; whence there is a continual Reciprocation between the animal and vegetable Kingdoms, which thus continually pass into one another, by the Mediation of the Atmosphere, Heat, and other natural Agents *b*).

6. That Composts, before they can produce their Effect, must in some Degree approach the Nature of the Soil they are design'd to improve *c*).

7. That by Earths are understood such gross Substances as are of themselves insoluble in Water, and indestructible in the Fire, yet with fixed Alkaly melt into Glass, or with any unctuous Matter assume the Form of a Metal, according to their respective Natures *d*); and consequently, that even Earths, tho' apparently exhausted simple Bodies, have yet their respective or peculiar Properties and Effects *e*).

8. That the most fixed Part of Earth has many Instrumental Efficacies, not only as floating in the Air, and as forming the Bed or Matrix of Vegetables; but also in constituting the solid Parts or Stamina of all vegetable, animal, and mineral Substances *f*), and affording us all our Vessels of Glass, Stone, Wood, Metal, our Furnaces, Crucibles and Tests, and being perhaps

a) See *Exp* I.

b) See *Let.* III. & *Exp* I. II. of the present.

c) See *Exp* I. & II.

d) See all the *Experiments*.

e) See above, §. 5, 26, 38.

f) See *Exp* I. II. &c.

in itself the most fixed and unchangeable Body in Nature *a*).

9. That a high Degree of Trituration, or reducing the Particles of certain Bolar Earths, Clays, and stony Earths to an extreme Fineness, may contribute to the Improvement of the Art of Pottery. For which Purpose, Trituration, Sifting, Subsidence in Water, and Decantation, might be used to advantage *b*).

10. That the making of Lime may be improved for the Purposes of Building, Manure, and Water-Works, by a due Choice of the Materials, and a suitable Calcination *c*).

11. That some considerable Use and Improvement might, with proper Skill and Application, be made in the Business of Marcasites and Mundicks; Bodies usually esteemed as Refuse, and intractable Stuff *d*).

12. That Marcasites, by attracting the Moisture of the Air, may be the efficient Cause of subterraneous Fires, hot Springs, Damps in Mines, Mineral Waters, &c. *d*).

15. That the Matter of Metals may possibly lie loose, immature, or unconcocted in certain Mineral Matters, so as in the Fire to fly away with the Sulphur, or other Parts of the Mineral; unless detained, and brought to greater Perfection either by Nature or Art *d*).

14. That Fire may have the same Effect as Air or Time, on certain stony Matters, and make them loose, crumbly, and incoherent *e*).

a) See § 15.

b) See *Exp.* III.

c) See *Exp.* IV. § 25. *Exp.* VI. § 36.

d) *Exp.* V.

e) *Exp.* V. & § 35.

LECTURE V.

CONTAINING

A Natural and Chemical Examination of Waters.

1. **O**UR present Business is the Chemical *The Sub-*
Examination of Waters; with a view *jea.*
to manifest their Natures, their Uses to
the Earth, and all vegetable, animal, and mine-
ral Substances; but particularly to Man, so far
as we can discover them.

2. By the general Name of Water we under-stand an extremely fluid, limpid, insipid, and *Water de-*
inodorous Liquor. This Definition is obvious, *fined.*
and taken from the direct Testimony of the
Senses; but by enquiring philosophically into the
Nature of Water, we shall find it possessed of
many unexpected Properties.

EXPERIMENT I.

That Water is contained in many solid and, to ap-
pearance, dry Bodies.

3. We took a Piece of the hardest and dryest *Found in*
Bone we could procure, and distilling it in an *dry Bones.*
Earthen Retort with Degrees of Fire, obtained
a very large Proportion of Water, along with
much Oil, and volatile Salt *.

* See this Experiment farther prosecuted in *Let. VIII.*
Exp. II.

4. This

4. This Experiment holds true even of the oldest Hartshorn, the dryest and hardest Woods, Earths, and pulverized Stones. Whence it appears, that Water may lie concealed in solid Bodies, and make a constituent Part thereof; as we formerly shew'd of Air *a*). For we do not here mean that Water insinuates itself into the superficial Pores of Bodies, as Wood, Skins, Leather, Parchment, Strings, &c. so as to swell them in moist Weather, and leave them shrunk in dry; but that it remains permanently intermixed as an essential Ingredient, or Part of solid Bodies, as in Stone, or Brick after baking, &c. Of this we gave an eminent Instance in our last Lecture *b*), where we shew'd that *Gypsum*, with Water, presently concreted to a stony Hardness.

5. If any doubt should arise, whether the Liquor obtained from the Bone in our Experiment be truly aqueous, we might shew it to Satisfaction, by separating the Oil, and turning all the volatile Salt contained therein to Sal-Ammoniac, by Means of a sufficient Quantity of Spirit of Sea-Salt; then rectifying the Liquor by repeated Distillation, and bringing it over in Form of a pellucid, insipid, and inodorous Fluid *c*).

6. It

a) *LeB. III Exp. X.*

b) *Exp. VI.*

c) To purify this Liquor absolutely, is a very laborious Task; but as some of the first Drops come over limpid, and almost insipid, before the Oil and Salt begin to rise, this may afford a strong Suspicion that the succeeding Drops are also aqueous, only mix'd with Oil and volatile Salt. For tho' the Bone were ever so thoroughly dried by the Fire, and the Vessels employ'd ever so free from Moisture, a large Proportion of the aqueous Liquor would still be obtained. Besides, the foul and fetid Liquor has been so far cleared from the volatile Salt and Oil, as to appear limpid, and prove insipid, and

6. It is therefore certain, that all Vegetables, and even the most solid Parts of Animals, naturally contain a large Proportion of aqueous Fluid, or actual Water, in their Composition; and that it remains in them unaltered in its own Nature, so as, when set free, to resume the Form of Water, after having been detained, or circulated therein for numbers of Years. Whence it should seem, that Water passes thro' all Natural Bodies, unchanged either by Accretion, Growth, Apposition, Fermentation, Putrefaction, Digestion, Distillation, &c. being chemically recoverable again from Vegetables and Animals, Wines, Vinegars, and Spirits.

EXPERIMENT II.

That Water may be collected from the dryest Air, or in the hottest Climate.

7. (1.) We put half a Pint of common Water *In the dryest Air.* into a cylindrical Glass, wiped perfectly dry on the Outside; then added to the Water, two Ounces and three Quarters of pulverized and dry Sal-Ammoniac. We now stirr'd them briskly together; whereupon the Water floating in the external Air was, by the Coldness thus produced as the Salt dissolved within, condensed on the Outside of the Glass, and trickled down in small Veins into the shallow Basen set underneath to receive it.

and inodorous. And as it approached nearer to common Water, after every Rectification, there is no doubt but, if a sufficient Quantity were procured, it might by Degrees be brought exactiv to resemble common Water, distilled and treated in the same Manner. But the easiest Way is to impregnate common Water with the Oil and Salt of the Bone; so as to make it resemble the Mixture that comes from the Bone into the Receiver upon Distillation. See more to this Purpose in *Let. VIII. Exp. I. § 14.*

8. This

*The Experiment
extended
and applied.*

1. This Experiment holds in all Climates and Places, of whatever Heights, where it has been tried. Whence, by the Law of Induction, we may make it universal, till any contradictory Instance appears. Thus therefore it may hold in the most parched Countries and hottest Seasons, so as to afford an agreeable Method of cooling potable Liquors, and rendering them more refreshing. For if the Glass containing the Salt and Water be set in any Liquor, the Liquor will become cooler as the Salt dissolves. And if any considerable Improvement could be made in the Contrivance, it might serve in some Measure to supply the thirsty Traveller in parched Desarts, and Sailors with fresh Water at Sea: nay, it has been a Practice among the latter to hang out Fleeces of Wool on the Sides of the Ship over Night, and to squeeze fresh Water out of them in the Morning.

9. The same Experiment, being carried higher, affords us a Method of procuring a Degree of freezing Cold, in the hottest Countries, at all Seasons of the Year. For if a Quantity of dry and pulverized Sal-Ammoniac be separately included in one well-closed Glass, and a proper Quantity of common Water in another, and if both these Glasses be put into the first Solution, whilst the Salt is dissolving, both the confined Salt and Water will soon acquire the same Degree of Coldness as the first Solution; and being then taken out, and mixed together, they will form a second Solution much colder than the first. And thus by repeating the Experiment twice or thrice, with fresh Salt and Water, a Degree of freezing Cold may be soon obtained in the hottest Climate.

EXPERI-

EXPERIMENT III.

That an Earthy Substance is naturally contained in Water.

10. (1.) We filled three several Glasses with pure *Water* Rain Water, Spring-Water, and *Thames-Water*, *contains* and let them stand close covered for some Days *Earth*. before they were exhibited: there was an earthy Sediment then deposited in all three, but most in the *Thames-Water*, the Sediment whereof was not only larger, but also more foul and muddy than in the Rain-Water; tho' here also it was dirty, perhaps because not carefully collected: whereas in the Pump-Water, it was white, scaly, flaky, and shining, like fine Spangles of Talc.

11. This Experiment also is universal, so far as it has been tried with Care, and holds true of the Waters of all Species and all Countries; particularly in those called Mineral Waters, from which an earthy Substance may usually be precipitated by Art, in a considerable Proportion: For Example, by the bare Addition of Salt of Tartar.

12. Certain Experiments carefully made, and repeated, shew that the terrestrial Matter naturally contained in Water, has a principal Share in the Growth and Increase of Vegetables; all the Plants that thrive in Water, appearing to enlarge their Bulk in Proportion to the earthy Matter furnished by the Water. Whence pure Elementary Water seems but a Kind of Vehicle to convey this nutrimental or substantial Part, and depofite it in the Vessels through which the Water moves, in order to its general Exit at the Surface of Vegetables*. Yet we are not here

* See Dr. Woodward's Experiments to this Purpose, in the *Philosophical Transactions*.

*Office and
Use of Wa-
ter.*

to exclude the Instrumental Efficacy of the two other Elements, Fire and Air. Now this appearing to be the general Office of Water, in the whole Vegetable and Animal Kingdoms, viz. the Conveyance or Distribution of the alimentary Matter to all their Parts, it may be proper to consider its Physical Properties, which wonderfully fit it for this Office.

*Its Proper-
ties.*

13. The Figure of its component Parts appears to be smooth and spherical, like those of Quicksilver, whence it becomes extremely moveable and penetrating. Thus it readily enters the Pores of Wood, Leather, Skins, Chords, Musical Strings, &c. and thus it likewise becomes capable of moving and agitating Particles of Matter less active than itself, and so proves the more immediate Physical Agent of Fermentation, Putrefaction, Solution, &c. And thus it also conveys earthy and saline Matters thro' our Filtres of Paper, Stone, &c. and even raises some Proportion of them in Distillations.

14. Its Particles likewise appear to be extremely minute, and so to have a large Share of Surface. Hence Water is admirably fitted for a Solvent, or for readily entering the Pores of Salts, and coming into full Contact with all their Particles. And thus it will pass, where Air cannot, on Account of its Moisture, or lubricating Power, whereby it softens mucilaginous Matters, and will therefore soak thro' the close Pores of a Bladder. And being thus qualified, it seems extremely well fitted to enter or slide thro' the fine Canals and Vessels of Plants; so as to convey nutritious, saline, or earthy Particles along with itself; and having deposited them by the Way, and being now robbed of all that is useful to the Individuals, it at length perspires into the open Atmosphere, in order to be there recruited and fitted

fitted for fresh Service. And the same kind of Office it performs in Animal Bodies.

15. Hence we may learn the physical Reason *That of Ri-*
 why River-water is more fertilizing than Rain, *vers why*
viz. because it contains more earthy Matter; *most ferti-*
 and why such Meadow and Pasture Lands, as *lizing.*
 lie commodious to be overflowed by muddy
 Rivers, yield greater Crops than such as are
 watered by other Means. Hence the incredible
 Fertility of *Egypt* appears to proceed from the
 turbid Overflowing of the *Nile*, and the same is
 to be understood, in some Degree, of other Rivers,
 as the *Ganges*, the *Thames*, &c a).

EXPERIMENT IV.

That Water saturated with one Body will still dis-
solve another.

16. (1.) We took four Ounces of pure cold *The dissol-*
 Rain-water, and dissolved therein as much dry *ving*
 common Salt, reduced to Powder, as it would *Power of*
 take up. The Salt used being Part of a known *Water.*
 Quantity, we weighed the Remainder, to find
 precisely how much had been employ'd, and
 found it about an Ounce; which therefore gave
 the Measure of the Power that the Water had to
 dissolve common Salt, with the Degree of Heat
 then present in the Atmosphere. To this satu-
 rated Solution of Sea-Salt we added about two
 Scruples of dry pulverized Nitre, and found
 that it dissolved therein, tho' no more common
 Salt could be taken up by the Water.

17. This Experiment is only particular; for
 the dissolving Power of Water is different on

a) See *Boyle's Abridgment*. Vol. I. pag. 248. &c. and
Lowthorp's Abridgment of the *Philosophical Transactions*,
 Vol. II. pag. 725. &c.

different Subjects *a)*. Whence a Set of Experiments should be made, to shew this Power on all the Salts, and other Subjects, whether mucilaginous, gummy, earthy or others, that are capable of dissolving in Water. Such a Set of Experiments might prove of considerable Use in physical and chemical Enquiries, and help to rectify the Mind, which is extremely apt to form general Rules from a few particular Instances. Whence Water has often passed for a Kind of universal Solvent; tho' there are numerous Bodies which it will not dissolve *b)*. And from this erroneous Notion of a general dissolving Power in Water, the Enquiry into Mineral Waters has been in great Measure either stopped, or perverted *c)*.

18. The limited Power which Water has, of dissolving common Salt, appears remarkably in the Ocean; which we see, by our Experiment, may naturally contain about one fourth Part of such Salt; or, with an additional Heat, considerably more; tho' its Charge is always limited by the Nature of the Thing, and cannot be above one certain Proportion. This, however, is found to differ in different Seas, or Bays; the Water of some being found to yield more Salt than others, according to the greater Heat or Exhalation of Vapor in those Seas or Bays; or again, perhaps, according to the Opportunity which the Water has had of running upon a more saline Bottom &c.

19. But when Water has dissolved its full Proportion of common Salt, we see, by the

a) As will appear hereafter. *Lect. VI. Exp. I.*

b) As Stones, Metals, Glafs, Gems, Amber, Shells, Coral, Sponge, Cloth, &c. See hereafter *Lect. VI. §. 15.*

c) See the *Appendix to New Experiments and Observations upon Mineral Waters*, lately published.

Experiment, that it may still dissolve some Quantity of another Salt. And how far this Power may extend, as to the Matters at the same time dissolvable in Water, has not been hitherto sufficiently ascertained *a*).

20. Nor is the Method, wherein different Salts range themselves in the same Water, precisely determined. That they do not intermix, so as inextricably to entangle and confound their Particles among one another, appears from Crystallization. For if several different Salts be dissolved together in the same Parcel of Water, they may be made to shoot separately out of it again, by repeated Evaporation and Crystallization, each in its own natural Form and Figure, or pure and unmixed with the rest. But the Power of Water as a Solvent will again come to be considered in our next *Lecture upon Menstruums b*).

EXPERIMENT V.

The natural Ingredients or different component Parts of Water.

21. (1.) We took a Pint of the purest Rain-The Contents of Water. Water, decanted from its natural Sediment, and put it into a bellied Glass, with a long slender Stem; then marked the Part of the Stem to which the Water rose, and set it in the exhausted Receiver, where we found it manifestly expanded, and discharged many Bubbles of Air. (2.) We put the same Water into a clean Glass Retort, and distilling with a gentle Heat into a Glass-Receiver, there came over a pure light Water, or merely aqueous Liquor; leaving a

a) See Dr. Grew and Mr. Boyle *p. 155*im.

b) See *Let. VI. Exp. 1.*

small Quantity of dry and whitish terrestrial Matter behind.

22. This Experiment requires a farther, and much more exact Prosecution. We see it resolves Water into three distinct, and, to appearance, different Parts; *viz.* (1.) Air, (2.) elementary Water, and (3.) Earth. The Truth of this Analysis seems confirmed by other Experiments. For Water, by boiling, is also deprived of the Air it naturally contains. And so it likewise is by strong Freezing, the Ice becoming gradually less porous, and more purged of its Air-Bubbles; also Water upon thawing always leaves a Quantity of earthy Sediment behind. But neither this Experiment of Freezing and Thawing, nor the Re-distillation of Water, has been carried so far as to shew, with Certainty, whether any, and what Proportion of the Water is thus actually convertible into Earth; or whether a Quantity of earthy Matter, before dissolved or finely dispersed in the Water, is thus only aggregated, or collected together and left behind, in a dry, solid, or earthy Form, upon Evaporation.

23. The Determination of this Point is of Consequence to Physicks. The Circumstances that tend to invalidate the Experiment by Distillation are, (1.) That the Water suffers a great Diminution of its Quantity in the Operation; some Part sticking to the Sides of the Vessels employed every Time, and some transuding thro' the Luting: whence the Account is defrauded. And (2.) that in transuding the Liquor, it every Time licks up the Dust naturally contained in the Atmosphere, and at the same Time loses Particles of Water, which are thus carried off by the Air; whence, upon numerous Repetitions of the Experiment, a large Proportion of the Earth obtained

tained may proceed from the Dust of the Atmosphere *a*).

24. The Experiment by Congelation seems attended with fewer Difficulties, and might perhaps be brought to determine the Point with less Expection, by using a Circle of Freezings and Thawings, alternately repeated, with Care to separate the Earth each Time.

25. What we here term Elementary Water, is the pure aqueous Part which comes over in Distillation, commonly called by the Name of distilled Water. This distilled Water is found to be lighter and purer than the natural; provided it acquire no Foulness, or heterogenous Parts in the Operation. And it is observable that, if the Operation be stopped in the Middle, a grosser Water remains behind than what came over. Whence, for all curious chemical and œconomical Uses, the Water employed should not boil too long; as particularly in the making of Tinctures, Tea, Coffee, &c.

EXPERIMENT VI.

The more commodious Methods of examining Water.

26. By Means of the Instrument called the *Common* Hydrostatical Balance, we took the specific Gravity of the Water proposed, and directly judged *Water examined.* of its Goodness by its Lightness.

27. This Experiment is a good Substitute for several other Ways of examining the Purity and Goodness of Waters, both common and mineral. For it appears by numerous Instances, that light Waters are, *ceteris paribus*, the best, purest and wholesomest.

a) See Mr. *Boyle's* Philosophical Works, and *Boerhaave's* Chemistry.

28. But as the present Method requires the Use of a curious Instrument, and a considerable Degree of Accuracy and Attention, other more expeditious, tho' not more exact, Trials have been invented; particularly by the Use of *Water-Poises*; which are Instruments of Ivory, Glass, &c. made hollow-bellied, so as to float in Water, higher or lower, according as the specific Gravity thereof is more or less: And the Instruments being graduated or divided by Lines on the Stem, readily shew to the Eye the Difference betwixt the specific Gravities of any two Waters proposed; tho' not with the utmost Exactness.

29. The Foundation of both Experiments is this, that the Bodies dissolved or licked up by Water, in its passing thro' the Caverns, or superficial Parts of the Earth, are generally either saline or earthy; which being both more ponderous than pure Water, it follows, that the lightest Waters are least impregnated with them, and therefore fittest for the finer Uses, where no such gross, saline, or earthy Matters are required; as they are not particularly in the healthy human Body, where the ordinary Office of common Water is to convey and distribute Nutriment to all the Parts, to dilute and wash off the Overproportion of animal Salts, as it evidently does in Sweat and Urine.

30. By Means of the present Experiment we find, that the purest Rain-Water is of nearly the same specific Gravity with distilled Water; neither of them, when obtained pure, precipitating any gross earthy Matter upon the Addition of Oil of Tartar *per deliquium*, as many Spring-Waters do.

31. Common-Waters are distinguished into *Hard* and *Soft*, and accordingly are used for different Operations. Thus soft Water is found best
for

for extracting certain Tinctures, freeing Metallic Calces from their Salts, &c. And hard Water is best for the tempering of Steel, the making of artificial Wines, and Malt-Liquors intended for long keeping.

32. Hard Waters are such as contain a foreign, saline or terrestrial Matter; and accordingly become softer by long standing, or by a small Addition of Salt of Tartar; both which tend to precipitate the terrestrial Substance out of them.

EXPERIMENT VII.

The more commodious Methods of examining Mineral Waters.

33. (1.) To half a common Wine-Glass of *Mineral* *Pyrmont* Water we added a Dram of the Syrup *Waters* of Violets, whereby a greenish Colour was produced. (2.) To a like Quantity of the same Water we added a few Grains of scraped Galls; and first, a purple, then a blackish Colour presently ensued. (3.) We evaporated a Quantity of the same Water, and a small Proportion of an ochry Substance was left behind. (4.) We set a Glass of the same Water, cold, in the Receiver of the Air-Pump, and found, upon, withdrawing the Air, that the Water sparkled violently, and discharged a numerous Quantity of small Bubbles at its Surface; like what happens in the Conflict of an acid and alkaline Liquor.

34. This Experiment holds in all the Cases of Chalybeate Waters only, and not of *Mineral Waters* in general. By Mineral Waters, in general, are meant all those wherein any Medicinal Virtues, besides those of common Water, are found. These Mineral Waters are of various Kinds: we may consider them under the general Titles of *Chalybeate*, *Purgative*, and *Alterative*.

35. The more useful and commodious Additions for examining these three Kinds of Mineral Waters, are, *Galls*, *Syrup of Violets*, and *Oil of Tartar per deliquium*.

36. *Galls* discover in them any small Proportion of Vitriol or dissolved Iron; as having the Property of immediately striking a purple, or black Colour, in all Waters, where any such Substance is lodged.

37. *Syrup of Violets* in the same Manner discovers any small Predominancy of an Acid or Alkali therein; by changing the Water red, if an Acid, and green, if an Alkali prevails.

38. *Oil of Tartar* discovers any small Proportion of earthy Matter, less capable of dissolving in Water than that Salt; by precipitating such earthy Matter, in Form of a white Cloud, to the Bottom of the containing Glass, where it collects, and appears like a subtile white Powder.

39. These Particulars may be shewn, and proved satisfactorily, by adding to pure Water a little of a known Acid, Alkali, dissolved Iron, and subtile Earth, or fine light Sediment of an earthy Water, and then applying the Syrup of Violets, Galls, and Oil of Tartar respectively.

40. Suppose, therefore, any unexperienced Water to be examined; first, drop into it a little Syrup of Violets, and if this does not alter its Colour, but keeps its full natural Blueness, the Water is neither Acid nor Alkaline. If Galls do not turn the Water black, it is not Irony, nor Vitriolic; and if Oil of Tartar does not precipitate a white Powder, the Water holds no considerable Proportion of earthy Matter.

41. The present Set of Experiments is capable of great Enlargement, by Means of many other Additions, fitted to produce a Change of Colour, or a Precipitation in Waters, according

as

they are impregnated with Matters of certain Kinds. Thus a Solution of Silver, by causing a Thickness or light Precipitation, discovers a minute Proportion of Sea-Salt contain'd in Waters. And there is scarce a Salt, an Earth, or a Mineral, hitherto known, but the Industry of the Chemist has found Means of discovering, if it be contained in any common or Mineral Water; especially, if to this we add the Use of Evaporation, or the Way of bringing the solid Contents of such Waters to a dry Form. So that if this whole Affair were to be properly conducted, we apprehend it might in a short Time terminate in a certain Discovery of the Contents of all the Mineral Waters of the Kingdom; to the great Advantage of ordinary Life, and a considerable Improvement in the Art of Medicine, and many other mechanical Arts and Trades, depending upon the proper Choice and Use of Waters.

EXPERIMENT VIII.

That Mineral Waters are imitable by Art.

42. We took a Quart of the lightest and purest Water we could procure, and added to it about thirty Drops of a strong Solution of Iron made with Spirit of Salt, a Dram or more of *Oleum Tartari per deliquium*, and twenty, thirty, or forty Drops of Spirit of Vitriol; but so as that the Alkali of the Oil of Tartar might prevail: we now shook all briskly together, and poured out a Glass for tasting; upon which, it was found very remarkably to resemble *Pymont-Water*. *Pymont Water imitated.*

43. This Experiment, tho' but particular, may afford us a general Rule for imitating any Mineral Water proposed. The Rule is, by a proper Analysis to find the Contents of such a Water,

Water, and their Proportions, by Evaporation, the Addition of tinging Ingredients, &c. as above mentioned *a*); then, by Means of synthetical Chemistry *b*), to compose a similar Mixture. Thus, for Example, we learn, by a proper Analysis, that the Ingredients or different constituent Parts of *Pymont-Water* *c*), are a subtile aqueous Fluid, a volatile Iron, and a predominating Alkali; all joined together into one brisk, pungent, spirituous Water: And upon this Analysis our preceding Imitation was founded, by means whereof, if the Proportions be justly hit, the artificial *Pymont-Water* will greatly resemble the natural, and produce similar Effects in the Body; as has been found upon Experience *d*).

44. The Imitation of this spirituous Kind of chalybeate Water is by much the most difficult; and may perhaps be rendered more perfect, if, instead of using the Solution of Iron in Spirit of Salt, the purest common Water be boiled in a close Vessel, with a small Proportion of Okre, soft Iron Ore, or Pyrites; the rest of the Process being conducted as above set down.

*Purging
Waters
imitated.*

45. The Imitation of the common purgative Mineral Waters is facile: Thus *Epsom-Water* is imitated by barely dissolving three or four Drams of *Epsom Salt* in a Quart of pure Water, made somewhat brisk or quick with a few Drops of Spirit of Vitriol and Oil of Tartar *per deliquium*, so as to let the Alkali prevail. And the same is to be understood of any other Water, the Contents of which are exactly known.

a) See *Exp. VII.* §. 35, 36, 37, &c.

b) See hereafter the *Lecture* on Synthetical Chemistry.

c) See above *Exp. VII.*

d) See New Experiments and Observations upon Mineral Waters.

46. And by a little farther Experience and Application, we apprehend that these Imitations might be brought to a great Degree of Perfection; so as to render the Trouble and Charge of importing foreign Waters, or going to drink them abroad, in a Manner unnecessary.

But the Imitation of the alterative Waters, such as those of *Bath, Buckston, Holt, &c.* has hitherto scarce been attempted; nor can be rationally, for Want of their respective just Analyses, upon which such Imitations should always be grounded.

AXIOMS and CANONS.

1. We have seen, (1.) that Water is naturally contained in some of the dryest and hardest Bodies, and in the dryest Air; (2.) that it itself naturally contains Air, and an earthy Substance; (3.) that it is the proper Menstruum of Salts, dissolving more of one and less of another; (4.) that one good Sign of its Purity and Wholesomeness is its Levity; (5.) that the Ingredients of a mineral Water may be discovered by chemical Experiments; and (6.) that mineral Waters are imitable by Art, guided by such Discovery *a*).

2. That Water is of infinite Use in all the Works both of Nature and Art, as without it there could be no Generation, Nutrition, or Accretion performed in all the animal, vegetable, mineral, marine and atmospherical Regions. The Blood could not flow in the Veins, nor the Sap in the Vessels of Vegetables, nor the Particles of Minerals concrete and grow together, without Water. It is this that makes the largest Part of

a) See the *Lecture passim*.

our Blood, our Drink, and our Aliment. Without it there could be no Corruption, Fermentation, or Dissolution carried on *a*); no Brewing, no Distilling, no Wines, no Vinegars, no Spirits *b*).

3. That we meet with Water under an infinite Variety of Forms, and in an infinite Variety of Bodies; as of Air, Vapour, Clouds, Snow, Hail, Ice, Sap, Wines, Blood, Flesh, Bone, Horn, Stones &c. through all which it seems to pass unaltered, as an Agent or Instrument that suffers no Alteration by Re-action, but remains capable of resuming the Form of Water again upon Occasion *c*). In which respect it greatly resembles that other *Proteus* Quicksilver, which we meet within the Form of Fumes, Clouds, Sublimate, Precipitate, &c. from which it may be reduced to running Mercury again *d*).

4. That Water, in its common State, appears to be a Combination of all the Elements together, as containing a Quantity of Fire, which keeps it fluid, a Quantity of Air, and a Quantity of Earth *e*). Whence it can be no Wonder that Water alone, as it appears to the Senses, should suffice for Vegetation, in some Cases where little Earth is wanted; or for supporting animal and mineral Life, where no great Degree of Nutriment is required. And hence it proves a *Gluten* or Cement to some Bodies, and a Solvent to others. Thus it consolidates Brick, Plaister of *Paris*, Stone, Bone, &c. but dissolves Salts, and subtile Earths approaching to Salts, and becomes the instrumental Cause of their Action *f*).

a) See *Leß. I.* *b*) See the whole Work *passim*.

c) See *Exp. I.* &c. See also *Leß. III.*

d) See *Mr. Boyle* *passim*. *e*) See *Leß. I. II. III. IV.*

f) See *Leß. I.* the preceding *Lecture* *passim*; and again, the *Lecture* upon Fermentation, &c.

5. That Water conveys Nourishment, or a more fixed and solid Matter, to the Parts of Vegetables, where that being deposited the finer Fluid perspires into the Atmosphere *a)*; which gives us the physical Cause of the Dampness and Unwholesomeness of woody Countries, which they remarkably find in *America*. For all large Vegetables act after the Manner of Pumps, continually drawing in large Quantities of Water at their Roots, and discharging it at their Leaves; which intimates a Method of collecting Water in dry Countries, and also of making Salt-Water fresh.

6. That the Water in passing thro' Plants, after having deposited its more terrestrial Part, does not always go off pure, but impregnated with the finer Effluvia, or more subtile Particles of the Vegetable; thus making an Atmosphere round every Plant, odoriferous or otherwise according to its Nature: which supplies us with a Rule for procuring the odoriferous Waters of Vegetables by Distillation *b)*.

7. That the Particles, which are not fine enough to go off thus along with the Water, are left behind upon the Surface of the Leaves and Flowers of Plants; being now thickened or strained from their moister Parts, and remaining in the Form of Honey, Manna, Gums, Balsams, &c. according to the Nature of the Vegetable *c)*. And hence appears the physical Cause of Plants proving more odoriferous and sweet, when the Weather is both warm and moist; as immediately after a Summer's Shower.

8. That the chemical Operator should form to himself an *Hygrometer d)*, for the Service of his

a) See Exp. III. &c.

b) See Exp. III. §. 12. &c.

c) See Exp. III.

d) As of Sponge, Salt of Tartar, Oil of Vitriol, Oat-beards, &c. which attract the Moisture of the Air.

Laboratory, to determine the Proportion of Water at all Times contained in the Air; which continually mixes with his Preparations, differently augments their Weight, and promotes or hinders many of his Operations *a)*, as we find particularly in making the *Oleum Sulphuris per Campanam*. and *Oleum Tartari per deliquium*, both of which succeed best in a moist Air.

9. That pure Water makes the largest Part of mineral Waters, where it is impregnated as a Menstruum with several Ingredients, which it dissolves or takes up in its Passage thro' the Earth *c)*.

10. *Lastly*, The preceding Enquiry affords considerable Light for discovering practicable Ways of making Sea-Water fresh and potable *c)*; and of preparing Waters by Art, so as to render them fitter for the common oeconomic Uses, and the Service of many particular Arts; as Medicine, Pharmacy, Chemistry, Brewing, Distilling, &c. *d)*

a) See *Exp.* II. See also *Leç.* III, *passim*.

b) See *Exp.* VII. VIII.

c) See §. 7, 12, 14, & *Ax.* 5, &c.

d) See §. 40. &c.

LECTURE VI.

CONTAINING

*An Enquiry into the Nature and Use of
Menstruums, or Solvents.*

1. **W**E have now gone thro' the common *Introduc-*
Elements, Fire, Air, Earth, and *tion.*
Water: we next proceed to *Menstruums*, which
make a large Branch of Natural Philosophy, and
a more peculiar and immediate Part of Chemistry.
2. By *Menstruums* we understand all those Bo- *Menstru-*
dies, which, in a fluid, or subtilized State, are *ums what.*
capable of interposing their small Parts betwixt
the small Parts of other Bodies, so as to divide
them subtilely, and form a new uniform Com-
pound of the two.
3. Hence solid Bodies, as well as Fluids, are *Solid and*
capable of becoming *Menstruums*, when their *Fluid.*
Parts are subtilely divided, so as to receive others
uniformly between them; whether this subtil
Division and joint Interposition of Parts be ef-
fected by Fusion, Triture, or the like.
4. Thus when two Metals, being fused toge- *The Defi-*
ther, mutually interpose their subtil Parts be- *nition illu-*
tween each other, and unite into one uniform *strated.*
Mass, they become *Menstruums* to each other.
And so when common Sulphur and common
Mercury are barely rubbed together, till the
Mass becomes every Way uniform and similar,
the Sulphur proves a *Menstruum* to the Mercury,
and the Mercury a *Menstruum* to the Sulphur;
and

and both uniting form that black uniform Powder called *Æthiops Mineralis*.

5. Whence it appears, that the Term *Menstruum* is equally applicable to both the Bodies concerned; the one being as much a *Menstruum* as the other. So when Water dissolves Sugar, it may as justly be said that the Sugar dissolves the Water; tho' Custom, and the common Forms of Speech, which have little Regard to just and philosophical Notions, do not authorize the Expression.

*The Men-
struums of
Nature.*

6. And hence it may appear that the common Elements, which we have considered in the foregoing Lectures, are in a proper Sense the *Menstruums of Nature*, which she employs for producing her ordinary Effects. For Fire mixes uniformly among Bodies, and divides their Parts; so does Air, Water, and elementary Earth, as we have all along shewn. We suppose it will not therefore appear foreign, but directly conducive to our Purpose, to have bestowed a Lecture upon each of these Elements, by way of Foundation for our Course; as these are not only the principal Agents of Nature, but are also concerned in every chemical Operation.

*The Pur-
port of the
Experi-
ments.*

7. The present Business will be to shew, (1.) the different dissolving Powers of Water, on different Bodies. (2.) The same of Alcohol. (3.) The same of Oil. (4.) The same of unlikely Substances. (5.) The same of Quicksilver. (6.) The same of the common Menstruums, *Aqua Fortis* and *Aqua Regia*. And (7.) the same of the Digestor: thus proceeding gradually from the weakest up to the strongest dissolving Powers hitherto known in Chemistry.

EXPERI-

EXPERIMENT I.

That Water, as a Menstruum, dissolves more of one Body, and less of another.

8. We took three similar and equal Glasses, *The different Powers of Water, as a Menstruum.* each containing two Ounces of the same Kind of Water, cold; into the first we put a certain weighed Quantity of *Epsom* Salt, viz. two Ounces, the greatest Part whereof was soon dissolved; into the second we put a certain weighed Quantity of dry and pulverized common Salt, viz. five Drachms, which likewise soon dissolved almost entirely; into the third we put a certain weighed Quantity, viz. eight Grains, of finely pulverized *Cream of Tartar*, whereof scarce any Part appeared to dissolve in the cold. We set all the Glasses in *Balneo Mariae*, till the Water of the *Balneum* boiled, and then observed that more of each Salt was taken up respectively.

9. It might be proper, for the further Improvement of Chemistry and Natural Philosophy, *The Experiment extended.* to form a Table of the Time and Quantity wherein all the known Salts are dissolvable in Water. *Epsom* Salt, we see, presently dissolves in about an equal Quantity of Water; common Salt dissolves in about four times; Nitre in about five or six times; and Salt of Tartar in about twice its own Quantity of Water: but *Cream of Tartar* requires twenty times its own Quantity of boiling Water to dissolve it.

10. Such a Table, regularly formed, might ease the Trouble of refining Salts, by shewing at once, without future Trial or Loss of Time, how much Water each Salt required to dissolve it, for Clarification, Filtration, or Crystallization.

11. It would likewise supply us with a ready and commodious Way of separating any Mixture

of Salts, by shewing which would first shoot out of the Mixture upon Crytallization. For the Rule is, that *the Salt which requires the largest Proportion of Water to dissolve it will shoot the first*. And thus Nitre, requiring a larger Proportion of Water to dissolve it than common Salt does, the former is, in the ordinary way of refining, totally separated from the latter by Crytallization. And unless this were to happen, the *Aqua-Fortis* prepared from Nitre would prove a kind of *Aqua-Regia*, and, instead of dissolving Silver, would dissolve Gold; For *Aqua-Regia* is made from a Mixture of Nitre and Sea-Salt, or Sal-Ammoniac, which contains the Spirit of Sea-Salt*.

12. The same Table might also direct us to a ready and commodious Method of separating two Salts, without waiting for Crytallization. Thus suppose *Tartar of Vitriol* mixed with *Epsom Salt*, if Water be poured upon the Mixture, it will presently dissolve the *Epsom Salt*, leaving the *Tartar of Vitriol* untouched, so that it may be decanted clear from it; because *Epsom Salt* easily and plentifully dissolves in cold Water, whereas *Tartar of Vitriol* dissolves slowly and sparingly in it. And the same is to be understood of other Mixtures of Salts.

*Accounted
for.*

13. If the physical Reason be demanded, why one Salt dissolves more readily in Water than another, we recommend it to farther Examination whether all Salts do not dissolve in Water with greater or less Facility, and in greater or less Proportion, according as they contain more or less of a gross, unctuous Substance, unsuitable to the Nature, or to the Fineness and Lubricity of Parts required in Water. The comparing of

* See hereafter *Exp. VI.*

Epsom Salt, Salt of Tartar, common Salt, &c. with Nitre, Alum, crude Tartar, &c. seem to make this more than a Conjecture.

14. Vitriols also, being a Species of Salts, thence become soluble in Water. But pure Water has not the Power of dissolving Metals, unless they are first reduced to a Saline or Vitriolic Form: Nor does Water act as a *Menstruum* upon Oils, Rosins, Amber, Sulphur, &c. Whence its Power, as a direct Solvent, is limited *. For Salts it seems the appropriated *Menstruum*; but, with the Assistance of other things, it may dissolve a great Number of other Bodies: Thus, by the Interposition of Wax, it will dissolve Oil by simple Triture; by means of the Yolk of an Egg it will dissolve Turpentine; and by means of acid Spirits it will dissolve Chalk, Earths, and Metals.

15. In our present Experiment we find the dissolving Power of Water increase with Heat; and this holds till the Water boils: after which, as the Heat remains the same, so does the dissolving Power, and as this Heat decreases, so does that Power, letting Part of the Salt fall down again. Whence it should seem as if Heat was the original Cause of the dissolving Power.

16. But on the other Hand, there are Experiments wherein the Power of Water, as a *Menstruum*, decreases, as the Degree of Heat increases; as in boiling the White of an Egg; where the Water, as it grows hot, coagulates the Subject which it would dissolve when cold. We also observe the same of Blood, a firm Mixture of Flower and Water, &c. The Instances of this Kind should therefore be collected, and go along with the former, to prevent the Mind from run-

* See Lect. V. §. 17, 18, &c.

ing into Error, by concluding hastily from too few Experiments, which has greatly prejudiced Chemistry and Natural Philosophy.

EXPERIMENT II.

The dissolving Power of Alcohol.

*Camphire
dissolved
in Spirit of
Wine.*

17. We took an Ounce of *Alcohol*, and by degrees added to it an Ounce of solid Camphire; all which it nearly dissolved, in a very short Time, without any Ebullition, or apparent Alteration of Fluidity or Transparency. We afterwards poured in a large Proportion of fair Water, which weakening the Solution, and uniting with the *Alcohol*, caused it to let go the Camphire; so that now it all rose, white, solid, and perfect, to the Top of the Mixture.

*Alcohol
what.*

18. *Alcohol*, or highly rectified Spirit of Wine, is a Liquor obtained from vegetable Subjects, by Fermentation, Distillation, and Rectification *a*). It appears related to Oil, because totally inflammable; and when carefully examined, to be the essential Oil of the Vegetable, intimately broke, and ground in among the Particles of Water; so as to form one uniform Liquor, not easily separable again into different Parts *b*).

19. We learn, by the present Experiment, that it has the Power of dissolving about its own Weight of Camphire; which when duly examined, appears to be a particular Kind of volatile, or essential Oil, coagulated into a white and solid Substance *b*): And, as such an Oil, it is here plentifully dissolved in *Alcohol*.

Its Uses.

20. This *Alcohol* is a capital *Menstruum* in Chemistry, and fitted to dissolve Rosins, as well

a) See the *Lecture* upon *Distillation* hereafter.

b) See hereafter *Lect. XVI. Exp. III.*

as Oils; tho' it does not thus mix inextricably with either, but leaves them separable again by the bare Addition of Water, which it dissolves more readily than either Oil or Rosin, and therefore lets them go to join with this, according to the Law of Precipitation. For *whenever one Body has dissolved another, if a third be added to the Solution, which third has a greater Relation to either of the former, than they have to each other, their Union is separated, and the third Body dissolved instead of the first or second; one of which is now at Liberty to rise, or fall to the Bottom, according to its specific Gravity: as we saw remarkably in the present Experiment, where the Camphire, dissolved in the Spirit of Wine, was soon made to float upon the Surface, by the Addition of Water, which has a greater Appetite of Union, or Relation, to Spirit of Wine, than that Spirit has to Camphire. And the physical Reason hereof may appear from what was just now said of the Composition of this Spirit, or its being an intimate Mixture of Water and volatile Oil **.

21. Hence *Alcohol* is an intermediate Substance betwixt Oil and Water, and related to both, tho' participating more of Water than of Oil: And according to these Relations, its Action as a *Menstruum* may, we conceive, be properly explained.

22. By means of this *Menstruum* the Tinctures of *Myrrh*, *Gum Lac*, *Guaiacum*, most of the Varnishes, and many medicinal Tinctures, Elixirs, and Solutions are prepared; tho' for these Purposes it usually requires to be acuated with Salt of Tartar. But our present Business is to consider the Power of simple *Menstruums*, rather than of such as are mixed; for that were an infinite Field, and would lead us too far for the present.

* See §. 18.

Tho' the Discovery of powerful, yet innocent *Menstruums*, by means of Composition, should be earnestly recommended to the Diligence of every Chemist, as that on which the Improvement of numerous Arts depends.

EXPERIMENT III.

That Oil will intimately dissolve Lead.

*Oil dis-
solves
Lead.*

23. We put two Ounces of crude Lead into an Iron Ladle, and added thereto twelve Ounces of Oil-Olive; then setting them over a clear Fire, the Lead evidently melted before the Oil began to boil, and at length the Lead disappeared, or united and became one with the Oil. By stopping the Operation at any time, we could easily learn how much of the Lead was dissolved in the Oil, both by the increased Consistence of the Oil, and the Diminution of the Lead.

*The Expe-
riment ex-
tended.*

24. The same Experiment may hold also of Tin, and of Tin and Lead mixed. How far it is applicable to the other Metals has not been hitherto satisfactorily tried. Some have supposed that Oil will dissolve Copper and Iron: But it should be carefully examined whether the effect be not owing to an Acid concealed in the Oil; for it is the known Property of Acids to dissolve these Metals. This has been observed, that if Oil be well boiled, to get out its aqueous Parts, it is the better fitted to preserve Utensils of Iron, Brass, or Copper, from Rust. Whence Marrow is reckoned better for this Purpose, than other Fats or Oils more subject to harbour aqueous Moisture: And if a little Ceruse, or Black Lead, be added in the boiling, the Oil becomes still more proper for this Purpose. Now it is the Property of Ceruse, and black Lead, to drink up Acids; and therefore it may be hence concluded, that

that some acid Parts, naturally contained in Oils, are the Cause of their Rusting or Dissolving the Iron, Brass, or Copper, on which such Oils are laid.

25. The Preparation, or Substance, obtained *Its Uses:* in the present Experiment, being taken from the Fire at different times of the Operation, makes either a Balsam, a Cement, or a Plaister; and so is fit for various Uses. As a Balsam, and a Plaister, it is serviceable in Chirurgery. As a Cement, it is excellent in Water-Pipes; and being laid upon hot Brick-work, or the like, fits it for holding Water. It also serves to hold crack'd Glasses together, so that they shall be as firm in the Crack, as in the Sound Parts.

26. But a more physical Use of the Experiment is, to shew the great Affinity which the soft and fluid Body of Oils, as a *Menstruum*, has with the solid Bodies of Metals, and how they may mutually, not only dissolve, but disguise and conceal each other; so that Metals shall be contained in Bodies where the Eye would never suspect them.

27. The present Experiment also affords some Light in the Doctrine of Solders, or, the Mixtures of metalline Matters, that will run with a less Degree of Heat than the Metal proposed to be solder'd, and tenaciously lay hold thereof. For Oil, or Grease, is an useful Thing to facilitate the running of these Solders; as we see in the Soldering of Lead and Tin, where the Plumber uses his Tallow, as the Tinman does his Rosin; by means whereof the Solder and the Metal are the better soften'd, and in some Measure dissolved and incorporated together.

28. We desire that this great Affinity betwixt Oils and Metals may be remember'd; as
H 4

The Relation betwixt Oils and Metals.

being of extensive Consequence in the Business of Metals, and more particularly in the sublimer Metallurgy; where certain Expressions, concerning the *Sulphur of Metals* may be understood to advantage, by taking them to mean an actually inflammable Substance, or Oil.

EXPERIMENT IV.

That innocent and unlikely Subjects may afford powerful Menstruums, shewn in Bread.

*Bread
distilled.*

29. We took two Pounds of common brown Bread, cut it into small Pieces, and put it into a Glass Retort. We placed the Retort in a Sand-Heat, and luting on a Receiver, distilled with a moderate Fire, so long as any aqueous Liquor came over: at length suffering all to cool, we took off the Receiver, and by the Filtre separated the Liquor obtained, to clear it of its Oil. This Liquor we rectified from its Phlegm in *Balneo Maria*, and afterwards distilled it over again in a Sand-Heat, so as to obtain a moderately strong, acid, limpid Liquor, under the name of the rectified Spirit of Bread.

*Uses of the
Experi-
ment.*

30. In this manner we obtain from common Bread a large Proportion of an aqueous Liquor, mixed with acid Parts, so as to be capable of extracting the red Colour out of Coral, or even Garnets. But to procure this Liquor in its greatest Strength and Perfection, we should make Use of Rye-Bread, or some of the coarser sorts.

31. The Experiment being duly prosecuted, affords us the Analysis of Bread; a Substance capable of recruiting and forming all the solid Parts of our Bodies. And no wonder, since it contains nearly the same Principles as animal Matters. For Blood, Flesh, or Bone, upon their Analysis, resolve into Water, Oil, volatile Salt, and

and Earth; the whole, by Decoction, making a Kind of mucilaginous, or gelatinous Substance with Water: And in the same manner Bread boils with Water into a gelatinous or mucilaginous Substance, and when distilled, resolves into Water, an acid Spirit, Oil, and Earth. The principal Difference between them is, that Bread affords a volatile *Acid* by Distillation, whereas Flesh, or Blood, affords a volatile *Alkali*. Whence it should seem, that there is in the Body a certain Power of Changing the Matter of an *Acid* into that of an *Alkali* *.

32. To gain a clearer Information from the present Experiment, we could wish it were repeated with such Bread as contains no Sea-Salt, which is a common Ingredient in the usual Kinds of Bread. For Sea-Salt affords a considerable Proportion of acid Spirit upon Distillation, and this Spirit may have a great Share in dissolving the Bodies supposed to be dissolved by the Spirit of the Bread. But however that Matter may prove, the Experiment shews a powerful *Menstruum* is obtainable from an innocent and unlikely Subject. And the same has been found to hold of many other Preparations; as Wine-Vinegar, tartarized Tartar, &c. Whence the like Experiments should be tried upon other common Subjects, such as the Yolks and Whites of Eggs; Rennet, Curd, Whey, Milk, Butter-Milk, Cheese, Urine, &c. in order to discover whether serviceable *Menstruums* might not be thus procured. *Extended.*

EXPERIMENT V.

That Quicksilver dissolves Metals.

33. We melted two Ounces of clean Lead in an Iron Ladle, and in another Ladle we heated *Amalgamation of Lead.*

* See more to this purpose in *Lib.* VII.

the

the same Quantity of Quicksilver till it just began to fume; then we poured the Quicksilver to the Lead, and stirred them both together with an Iron Rod: upon letting them cool, they made a white, hardish, homogeneous Mass; a part of which, being ground with more fresh Quicksilver, readily and intimately mixed therewith.

The Experiment extended, with its Uses.

34. This Experiment succeeds with all the Metals, except Iron; which therefore appears of a less mercurial Nature than the rest. The Operation itself is called *Amalgamation*, that is, the intimate Mixing of a Metal with Quicksilver, and is the Foundation of Gilding and Silvering. For an Amalgam of Gold being rubbed upon a well polished Plate of pure Silver, and the Plate afterwards exposed to such a Degree of Heat as will evaporate the Quicksilver of the Amalgam, the Plate is left gilt. The Case is the same when Copper is to be silver'd. And thus Gold, or Silver, is uniformly diffused through the Body of the Quicksilver; whence a single Grain of Gold, Silver, Lead, or Copper, may be divided to an almost inconceivable Degree; or spread uniformly through a Mass of a thousand Pounds Weight of Quicksilver, every the smallest Particle of which shall contain a Quantity of Gold proportionable to the Whole. And hence it appears that Quicksilver is a true *Menstruum* to all the Metals, except Iron; dissolving them as perfectly as Water dissolves Salt.

35. The present Experiment also shews us how Quicksilver may be adulterated with a Proportion of Lead: but the Fraud is easily discovered, by putting a little Quantity of such debased Quicksilver into an Iron Ladle, and exhaling away all the Mercury which will thus leave the Lead behind.

36. We

36. We may likewise hence understand the fraudulent Tricks of some pretended Alchemists, who feigning an Occasion for the Use of Mercury in their Processes, do beforehand secretly dissolve, or procure to be dissolved therein, a certain Proportion of Gold or Silver; which not flying off along with the Quicksilver in the Fire, the credulous By-standers are made to believe, that the baser Metals employed are enriched with the nobler in the Operation. The Instances of such Frauds are many, and have brought a great Stain upon the Art of *Alchemy*. But they are easily detected, by exposing a Part of the Operator's Mercury to the Fire; for the Quicksilver going off in fume will leave the Silver and Gold behind.

EXPERIMENT VI.

That Aqua-Fortis, or Spirit of Nitre, is the Menstruum for Silver; and Aqua-Regia the Menstruum for Gold.

37. We took two Drachms of the finest Silver *Gold and* reduced to Filings, and poured upon it twice its *Silver dissolved.* Weight of proof *Aqua-Fortis*; then set the containing Glass in a gentle Heat, under a Chimney, till the Solution was perfectly made.

38. We took ten Grains of Leaf-Gold, and poured upon it two Drachms of *Aqua-Regia*; then set the Glass in a Sand Heat to warm thoroughly. After the Gold was dissolved we added a Grain or two more, till the *Menstruum* was fully saturated, and then decanted the clear yellow Solution. We afterwards put a few Grains of Silver into *Aqua-Regia*, and a few Grains of Gold into *Aqua-Fortis*; and kept the containing Glass warm, in the same manner as before, but found no Solution ensue in either case.

39. Thus

39. Thus we see that Gold and Silver are perfectly dissolved in their respective *Menstruums*, neither of which will touch the other Metal. For if any Gold be contained in the Silver, it will fall to the Bottom of the Solution in the form of a black Powder; and if any Silver be contained in the Gold, it does so likewise.

Proof-Aqua-Fortis
what.

40. The *Aqua-Fortis*, for the Solution of Silver should be made *Proof*; that is, it should be capable of dissolving half a Grain, or a Grain of Silver immediately, without growing in the least turbid; as it would do if it contained any Sea-Salt: in which Case it would be a Kind of *Aqua-Regia*.

How
made.

41. *Aqua Fortis* is made by distilling purified Nitre with calcined Vitriol, or rectified Oil of Vitriol, in a strong Heat, whereby an extremely corrosive acid Liquor is driven over in blood-red Fumes.

Aqua-Regia
what.

42. *Aqua-Regia* is made by dissolving a fourth part of Sea-Salt in the *Aqua-Fortis* above mention'd.

Uses of the
Solution of
Silver.

43. If the Silver employed in the Solution were absolutely pure, the Liquor will be pellucid: but if any Alloy, or Copper, remain mixed with it, the Solution will have a bluish or greenish Cast. If a Solution of perfectly pure Silver be diluted with fair Water, it will still remain pellucid, without letting any thing precipitate. But if any saline Matter be contained in the Water, the whole will now turn thick or milky. The Solution of pure Silver, when properly weaken'd with Water, may be commodiously used for staining the Skin, or other animal Substances, black. And if white, grey, or red Hair be moistened with it, the Hair will soon become of a beautiful brown, or jet-black Colour. For which purpose it may be used with Safety, Care being taken not to touch the Skin therewith; for
thus

thus a Blackness would be occasioned, that requires many Days before it goes off again; but it disappears at length, by the Scarf-Skin peeling off, without causing any Pain, or leaving any Sore behind.

44. The Solution of pure Silver has an intolerably bitter Taste; tho' to the Eye it be not distinguishable from fair Water: In which we have an eminent Instance how Metals may lie concealed from the Sight, or remain lodged in unsuspected Liquors, and thence be introduced invisibly into other Substances. Whence the greater Caution should be used with all Pretenders to the Melioration and Transmutation of Metals.

45. This Solution of Silver is the Foundation of several medicinal and chemical Preparations; as the *Vitriol of Silver*, the *Lunar Caustic*, the *Silver-Pill*, &c.

46. The Silver is recoverable from this Solution, barely by suspending a Copper-Plate therein: For Copper being more easily dissolved by *Aqua-Fortis* than Silver, the Silver is thereby precipitated to the bottom, in the form of a Powder, which being washed and melted comes into a metalline Lump again. And this is also to be understood of the Solution of Gold.

47. But, on the other hand the Solution of Gold is yellow, or gold-coloured, and tinges the Skin purple, as the Solution of Silver stains it black. It may be further added, that if the Solution of Gold be precipitated with Salt of Tartar, and the Powder carefully dried, it makes the *Aurum fulminans*, so called from the violent Explosion with which it goes off, when heated beyond a certain Degree*.

* See hereafter the *Lecture upon Pyrotechny*.

EXPERIMENT VII.

The dissolving Power of the Digestor, an Instrument contrived at once to direct the Action of Water, Air, and Heat, in a high Degree, upon a Subject.

The Structure and Use of the Digestor. 48. The *Digestor* is a strong Vessel made of Copper, or Iron, and fitted with a close Cover and Screws, so as to remain perfectly tight, in a considerable Degree of Heat; whilst Water, common Air, and the Subject of the Operation are contained within.

Ox-Bone soften'd. 49. We took a Pound of fresh Ox-Bone in a single Piece, with two Quarts of common Water, and leaving a considerable Space for the Atmospheric Air, we screwed them all up together in the *Digestor*, and applied a moderate Degree of Heat to the Bottom thereof, for about a quarter of an Hour, or till a Drop of cold Water, let fall upon the Cover, would evaporate in a very few Seconds of Time: after which letting all cool, we opened the Vessel, and found the Bone soft and tender, so as to be cut with a Knife, the Water about it turned to a hard Jelly, and a large Quantity of Fat in a solid Cake at the Surface.

Rationale of the Experiment. 50. The Effects of this Instrument will not appear surprizing, if the Forces that act within it be duly consider'd. For, as we have formerly shewed the instrumental Efficacy of Fire, Air, and Water to be very great, even when separate, it is no wonder they should act extremely strong upon a Body in conjunction*.

Its Uses. 51. Hence the *Digestor* seems, of all the Instruments, or Vessels, hitherto invented, the most

* See the five preceding Lectures, *passim*.

Of Menstruums.

III

powerful for increasing the Action of *Menstruums*. And if a suitable Method could be discover'd for strengthening the Engine, so as to work safely with a very strong Degree of Heat, we might reasonably expect to perform some very extraordinary Operations by its means, in the way of Extraction, Decoction, Tincture, Solution, and perhaps even Destruction, or Transmutation *a*).

52. But a Course of Experiments and Lectures upon this Engine alone, would scarce be sufficient to shew and explain its numerous Uses and Applications for improving the Doctrine of *Menstruums*. And what Effects the common Solvents, as *Alcohol*, *Oils*, *Aqua-Fortis*, *Mercury*, and Metals themselves, might have, when assisted by this Engine, is not easy to foretel; and indeed it would require much Industry and Application to discover them.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, that Water is a *Menstruum* which, of itself, dissolves little more than Salts *b*); but, being assisted by Acids, dissolves Earths, and even Metals themselves *c*). And hence might be drawn a *general Rule of Practice*, for making Water an almost universal *Menstruum*. Thus, by the Addition of a fixed Alkaline Salt, it dissolves Oil into a Soap; by the Addition of *Alcohol*, it extracts the resinous Tinctures of Vegetables: and in this Manner it might be proper to run through the different Subjects of the vegetable, animal, and mi-

a) See Dr. *Papin's* Treatise of this Instrument. See also the Lord *Bacon's* Philosophical Works, *passim*.

b) *Exp. I.* See also *Lect. V.*

c) *Exp. I, VI.*

neral

neral Kingdoms, and form Tables of the solutive Powers of Water, simple and compounded.

2. That such Tables may be readily formed of the dissolving Powers of all the known *Menstruums*, to shew by Inspection, in what Time, in what Proportion, and with what Degree of Heat, all Solvents perform their Action; which being once reduced to a Certainty, would greatly facilitate and improve the Practice of Chemistry *a*).

3. That the Power of *Alcohol*, as a *Menstruum*, is chiefly limited to Rosins and Oils; but, by certain Additions, may be extended, as was said of Water, so as to become an almost universal Solvent *b*). Thus, by the Addition of Water, it becomes Brandy, or Spirit, which extracts many Tinctures that neither pure Water nor pure *Alcohol* will separately extract. Whence we have a good Instruction for attempting a new Set of *Menstruums* by Mixture, or the Composition of two or three simple Solvents. And if the requisite Care and Skill were employed in this Matter, many useful Discoveries might be justly expected from it. Indeed, the mixing of two *Menstruums* may sometimes destroy the Virtue of both: thus Spirit of Nitre and simple Water will each of them separately dissolve the human *Calculus*, but when mixed they will not touch it. This Instance however is only particular, and there are a large Number producible on the contrary side; which may rationally recommend a farther Prosecution of this Enquiry.

4. That Metals are soluble in Oils, and in acid Spirits, so as not to be easily discovered therein *c*). Whence a Rule may be drawn for a prudent Suspension of the Judgment, and a rational Dis-

a) Exp. I. See also *Lect.* V.

b) Exp. II.

c) Exp. III. VI.

trust of the Senses in chemical Operations: And also, a Caution against being imposed upon by the vain Pretences of Alchemists *a*).

5. That the Power of a *Menstruum* is not to be judged of by its Innocency with regard to the animal Body. The acid Spirit of Bread is innocent and wholesome, yet capable of dissolving Coral and Gems *b*). Pure Oil-Olive will dissolve Lead and Tin. The White of an Egg, boiled hard, and suffer'd to run *per deliquium*, dissolves the tough Body of Myrrh. The Instances of this Kind are extremely numerous. They well deserve to be collected and tabled, that the Mind may be thereby cured of the Prejudice it has too readily imbibed, as if Corrosives only were Solvents.

6. That the Action of *Menstruums* depends upon a certain Secret and reciprocal Relation betwixt the Solvent and Solvend, scarce cognizable by the direct Senses, nor hitherto well made out by Instances and Induction. Alkali and Acid, Attraction and Repulsion, Sympathy and Antipathy, seem rather Words coined to express the Action, than to assign the physical Causes thereof. And hence the Action of new *Menstruums* cannot be determined, or rationally conjectured, beforehand; because it depends upon a Cause not hitherto known.

7. That *Menstruums* have not their full Action, unless reduced to a fluid or subtile State *c*). Water in the firm and solid Form of Ice does not act on Salts; but they soon begin to dissolve each other upon Contact. Metals do not act on Metals, in the Way of Solution, till they are fused: Nor does Sulphur dissolve Quicksilver, till they are both reduced, either to a fluid or very sub-

a) See above, §. 26, 33—36.

b) *Exp.* IV.

c) See the *Lecture*, *passim*.

tile State, by Triture, or by Melting. And this appears to be the Case in all Instances. Whence, in order to promote the Action of *Menstruums*, we are directed to reduce both the Solvent and Solvend to minute Parts, or as near as possible to a fluid State, whether by Heat, Triture, Fusion, or otherwise. And hence appears the physical Cause of the singular Efficacy of Fire, Air, Water, and Trituration in promoting the Action of *Menstruums* a).

8. That Quicksilver is a true Solvent of Metals, incorporating with them, as Water does with Salts b); by which Means one Metal may be readily united with another, in any Proportion, by simple Triture c). And hereby also many Operations in the sublimer Metallurgy are chiefly performed d).

9. That acid Spirits are not, equally, proper *Menstruums* to all the Metals; thus Spirit of Nitre, tho' it dissolves the rest, will not dissolve Gold e). So neither is Quicksilver itself a proper *Mensstruum* to them all; for it does not dissolve Iron f). And the true physical Reason hereof seems not hitherto satisfactorily discovered, tho' numerous Conjectures have been made about it.

10. That all the Bodies in nature may become *Menstruums* to one another, each of them being, by some Means or other, capable of having their small Parts uniformly interposed betwixt the small Parts of any of the rest. Thus even Metals may, by Art, be made to dissolve in Water; as we evidently see from numerous Solutions of Metals

a) See the five preceding Lectures, *passim*.

b) Exp. I and V. See also *Lect. V*.

c) See above, §. 33, 34.

d) See hereafter the Lectures on *Mineralogy* and *Metal-lurgy*.

e) See *Exp. VI*.

f) *Exp. V*.

in acid Spirits : these Spirits being no more than Water charged with the fine or more volatile Parts of Salts.

11. That the Cause of Solution commonly assigned, *viz.* the Admission of the fine Particles of one Body into the Pores of another, whose Figure is fitted for their Reception, is not just or adequate, but hypothetical and ill-presumed, since we find that some Bodies will uniformly dissolve their own Quantity of others *; as Water does of *Epsom Salt*, *Alcohol* of essential Oils, *Mercury* of Metals, one Metal of another, &c. ; whereas the Sum of the Pores, or Vacuities, of every Body must be necessarily less than the Body itself; and consequently those Pores cannot receive a Quantity of Matter equal to the Body wherein they exist : for this were to make the contained Matter bigger than the Pores that contain it.

12. That the dissolving Power of Water may be immensely increased by means of the *Digestor*, an Instrument not hitherto introduced into Chemistry, tho' probably applicable to the great Improvement of that Art ; as being a Contrivance, which at once determines the Action of a Solvent upon the Solvend, with all the Advantages of Heat, Air, and Water, briskly agitated and confined, under a State of Compressure, so as to make them act like different Sets of Stampers upon the Matter to be changed. For this Engine at once employs all the four Agents required to make the greatest Part of *Menstruums* act with Advantage ; *viz.* Fire, Air, Water, and Triture. Whence there are some solid Grounds of Hope, that it may, under a proper Regulation, greatly contribute to the Improvement of Chemistry, Natural Philosophy, and Arts.

* *Exp.* I. II. V.

13. Upon the whole it should seem, that many desirable Improvements are derivable to Arts from an Improvement in the Business of *Menstruums* *. The Discovery of that common *Menstruum*, *Aqua-Fortis*, introduced the Art of Assaying, and the Scarlet Dye. That of *Alcohol* introduced the Arts of Varnishing and Japanning, numerous Pigments for Painters, Colours for Dyers, Tan-Liquors for Tanners, the Staining of Bone, Horn, Ivory, Marble, various Kinds of Ink, Tinctures, and Solutions, in Medicine, Chemistry, and other Arts, have all resulted from the Discovery of *Menstruums*. Yet the Subject seems almost as new and rich as ever; so that numerous other Discoveries, of the same Kind, would not exhaust it.

* See the whole Enquiry. *passim*.



LECTURE VII.

CONTAINING

An Enquiry into the Nature, Office, and Effects of Fermentation and Putrefaction, in the Vegetable, Animal, and Mineral Kingdoms.

1. **T**HE Purport of this Lecture is to enquire ^{The Sub-} into the Nature, Effects, and Uses of ^{ject.} Fermentation and Putrefaction, as they are the natural Means of converting one Body into another; in order to acquire a farther Knowledge in the *Chemistry of Nature*, and thence derive some serviceable Rules for the Improvement of *Philosophical Chemistry*.

2. But as the Subjects of Fermentation and Putrefaction seem to have been imperfectly treated by Authors, and to lie buried, as it were, in Obscurity, we shall endeavour to let some Light in upon them by particular Experiments, and our Explanations of them; so as to shew the Steps of *Nature* and *Art*, in conducting and regulating these *capital Operations*, for altering and changing vegetable, animal, and mineral Subjects in the three grand Regions of Nature, viz. the *Earth*, *Ocean* and *Atmosphere*.

3. That we may proceed the more clearly, we ^{The Order.} shall begin with *Fermentation* in vegetable Subjects, and trace it thro' all its Stages; till at length it terminates in *Putrefaction*, which reduces vegetable Subjects to an animal Nature. We shall next consider the similar Process in animal

Subjects ; and *lastly*, examine whether any Thing of the same Kind obtains among Minerals.

I.

To begin with vegetable Subjects :

EXPERIMENT I.

The Nature and Uses of vinous Fermentation ; or the Way of changing the natural Juices of Vegetables into Wines.

*Wine
made from
Raisins.*

4. We took a Quarter of an hundred of whole, or unbruised, *Malaga* Raisins, and put to them seven Gallons of cold Spring-Water, in a wooden Vessel or Cask, which we let loosely cover'd in a warm Place, that the Contents might ferment for some Weeks. We found that the Water soaked thro' the Skins of the Raisins, dissolved their internal sweet or saccharine Substance, and became impregnated therewith, as a *Menstruum* ; that the Liquor manifested an internal Struggle and Commotion of its Particles, throwing up numerous small Bubbles to the Surface, with a considerable hissing Noise ; and that when the Fermentation was finished, the Liquor was become an actual new Wine, as appear'd by the Taste, Smell and Effects, having deposited a large Quantity of gross, earthy Sediment, called Lees, at the Bottom, different from the Husks, or Skins, and Stones of the Raisins.

The Experiment extended.

5. This Experiment is universal, or shews the general Manner of making Wines, and all other spirituous potable Liquors, or Drinks, by Fermentation. For, with a slight Change of Circumstances, it is applicable to the Brewing of Beer from Malt ; Mead or Metheglin from Honey ; Cyder and Perry from Apples and Pears
respec-

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respectively; artificial, or made Wines, as they are vulgarly called, from Cherries, Gooseberries, Currants, Elder Berries, Blackberries, Plumbs, Oranges, or other Fruit; also, from the Tappings of certain Trees, as the Birch, the Maple, the Sycamore, &c. and more eminently from the Juice of the Sugar Cane, Treacle, or common Sugar and Water. For any of these vegetable Juices, being duly fermented, afford as real and perfect Wine, according to their several Natures, as the richest Grapes of the best Wine-Countries.

6. To bring any of these Juices into a sound Wine, the Rule is to evaporate them, if they are naturally too thin, till they become of equal Richness with the Juice of the Grape, in Wine-Countries and in good Wine-Years. This may commodiously be done, by Means of the common Water-Poise *, which shews the Strength or Richness of Solutions to the Eye. And in general, any vegetable Juice, or Solution, is accounted sufficiently rich for making a strong Wine, when it will support a new laid Egg on its Surface. *And applied; with its Uses.*

7. The Wines made at present in *England* lie under a Disrepute; the Reason whereof seems chiefly owing, *first*, to the inartificial Manner wherein they are usually prepared, and, *secondly*, to a certain Rumour spread about them, as if they were unwholesome, crude, indigestible, too luscious, too tart or griping, and apt to occasion the Head ach, &c.

8. Those, who have never been in Wine Countries, nor otherwise made themselves acquainted with the Nature and common Preparation of

* See Lect. V. Exp. VI.

Wines proceed in their Judgment of them according to Report, popular Notions, and the immediate Information of the Senses. Thus, for Instance, Red-Port Wines, to please the common Palate, must be bright, deep-colour'd, rough, rich and racy, two or three Years old, &c. and when this or any other Notion comes once to be established as the *Criterion* of Wine, the Cooper is thereby directed how to hit the general Taste, and make a saleable Commodity.

Theory.

9. Upon the same Foundation *Philosophical Chemistry* instructs us to imitate the Wine-Cooper, and from almost any sweet and tart vegetable Juice, to make saleable Wines, even Sacks, Mountains, Sherries, or Ports; all of which by the way, are usually mixed Liquors, tho' the Basis of them all is the Juice of the Grape.

10. This Juice of the Grape being chemically examin'd and considered, proves to be no more than a large Proportion of real Sugar dissolved in Water, with the Addition only of a certain Flavour in the Juice of the Grape, according to the Nature of the Vine. Whence we lay it down as an *Axiom*, and the Result of a careful Enquiry, that a *saccharine Substance is the Basis of Wines*. For Sugar is not peculiar to the Sugar-Cane, but obtainable also from Grapes; and accordingly we often find large Grains thereof in dried Raisins; particularly in those of *Malaga*, that have lain for sometime, and sweated together, by which Means they run into Candy, a saccharine Efflorescence, and actual Grains of Sugar. So again, it is customary in *France* to evaporate the Juice of the Grape till it becomes coagulable in the Cold, and in this State to use it as a moist Sugar, under the Name of *Refiné*. And the same Thing is to be understood as practicable in Malt,

or

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or Wort, and the sweet Juices of all Vegetables that afford a Wine by Fermentation *.

11. Hence therefore we may derive a Set of *Rules*. Rules, for boiling down, or otherwise procuring the essential Matter of Wines in a small Bulk, and preserving it sound and serviceable for many Years, in order to the Making of all Kinds of Wines, Vinegars, and Brandies, even in Countries where no Vines grow. And this Discovery also affords great Light into the true Nature and Uses of *vinous and acetous Fermentation*.

12. To illustrate and confirm this Discovery *Practice*. by an Example, upon the Footing of the present Experiment: Take two hundred Weight and a half of double refined Sugar; put it into a Pipe, or Wine Vessel of two Hogheads; fill the Vessel within four Gallons of the Top with pure Spring-Water; set in a warm Place, or Wine-Vault; and three or four Pounds of fresh Ale-Yeast, or rather of new Wine-Yeast; and the Liquor in a few Months time will ferment into a sound, colourless, and flavourless Wine, and remain susceptible of any Colour or Flavour at Pleasure; so as with the Stain called *Turnsol*, to be made of the true Claret-Colour; and with a little essential vegetable Oil, of any particular Flavour required. And this is here deliver'd as an Experiment that succeeds to great Perfection; so as to shew a rational and practicable Method of producing Wines in the Sugar Colonies, or elsewhere, that shall rival those of *France, Italy, or Spain*; and if the Nature of Fermentation be well understood, the Process may be greatly shortened in point of Time, as well as improved in other Respects.

13. And so much for the Use of our present *Uses to* Experiment, with regard to Trade, and Oeco-*Trade*.

* See an Essay upon the Art of *Brewing and Distillation*. See also hereafter, *Less. XI. passim*.

nomy;

nomny. Its philosophical Uses are no less considerable. And first, it shews that the proper fermenting Matter of every fermentable Subject is but small, compared with the Quantity of Wine it affords. Thus, for Example, we see that four Pounds of Raisins may be diluted, and fermented, with eight Pounds of Water, into what is accounted a tolerably strong Wine. And yet even Raisins themselves contain a large Proportion of Water, besides their directly saccharine Substance; which saccharine Substance is reducible to a dry Form, as we find in Sugar. And whoever would thoroughly enquire into the Nature, the Uses, and the Means of improving *vinous* and *acetous* Fermentation, cannot perhaps do better than to chuse Sugar for his Subject; a chemical Analysis whereof will shew the Principles necessarily required in this Operation. These Principles appear to be an acid Salt, an Oil, and Earth so united together, as to be capable of dissolving perfectly in Water.

*To Philo-
sophy.*

14. Hence we also see the physical Cause of the fermentable Nature of River-Waters; which being kept in close Casks have been observed to ferment, and their Vapor, or Spirit, to take Fire at the Approach of a Candle. For much vegetable Matter, as Leaves, Grass, the Juices of Plants, &c. being by the Rains washed down into Rivers, such vegetable Matters must necessarily there run into a fermenting State, as Raisins do by the Addition of Water; the running or fluxible State of the Rivers being no Hindrance to this fermentative Motion, after it is once begun by Stagnation. For we see that Beer and new Wine will ferment afresh upon being shook, and carried upon Drays, or Carts.

15. All fermentable Bodies do not require *Ferments* to begin their Motion of Fermentation. Raisins,

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Raisins, we see, require none ; much less does the fresh expressed Juice of the Grape, or other vegetable Juices, in the Summer-Season, or in a warm Air. But all sweet vegetable Juices, that have felt much of the Fire, as Treacle, or Wort high boiled, Rob of Malt, Rob of Elder, or the like, usually require a considerable Proportion of a vinous Ferment to make them work. In general, Ferments are no more than Matters already in the Act of Fermentation, or that soon run into this Act: Of the first Kind are the Flowers of Wine, Yeast, fermenting Beer, or fermenting Wine, &c. and of the second, are the new expressed vegetable Juices of Summer-Fruits, &c.

16. Water, we find, is absolutely necessary to begin and procure a fermentative Motion in vegetable Substances. For Raisins, or Sugar, being kept dry, will never ferment. And this holds universally of all the Subjects of *vinous* and *acetous Fermentation*. Whence Water is an Instrument that must be necessarily employed in these Kinds of Fermentation, whether natural, or artificial *a*).

17. As the Water which naturally, and in large Quantities, perspires from the Surface of Vegetables, especially in hot Climates, does not go off pure, but carries along with it a considerable Proportion of fermentable Matter into the Atmosphere *b*), there may be an actually vinous Fermentation begun and carried on in certain Parts of that Region, especially where the Winds are still, or the Air stagnant. And what physical Effects and Uses this Fermentation in the Atmosphere may have, scarce seems to have been consider'd ; nor should they be rashly judg'd of, till a more thorough Enquiry is made. At

a) See *Lect. I. III. V. passim.*

b) See *Lect. V.*

Schiedam in *Holland*, a larger Quantity of inflammable Spirit is said to be obtained from Malt, than in any other Place, where there are fewer Malt-Distillers. This is probably owing to the Air of that Place being impregnated with the fermenting Vapours, that continually exhale from their numerous fermenting Backs and Stills. And the same is found to hold proportionably of Wines fermented in large Vaults or Cellars, where many Casks of Wine are at once, or successively, set to work.

18. Warmth, with the free Admission of the external Air, is necessary to expedite the Action of vinous Fermentation; for if our Raisins and Water were to stand either in a very cold Place, or to be kept entirely from the Access of the common atmospherical Air, either no Fermentation, or a very weak and slow one, would ensue; as has been experienced.

19. The Lees remaining at the Bottom of the Cask, in our present Experiment, are, if used fresh, a true Kind of *Ferment*, that will set any less fermentable Subject at work, and determine its Fermentation to the vinous Kind. They contain a large Proportion of essential Oil, and some Tartar. And hence we see that vinous Fermentation consists, *first*, in an intestine Struggle or Commotion of the Fluid; and, *secondly*, in a Separation of a grosser Part, which did not appear in that Form before.

EXPERIMENT II.

The Nature, Effects, and Use of acetous Fermentation; or the Method of turning vegetable Matters into Vinegar.

*Vinegar
made.*

20. We took the Skins of the Raisins, and the Sediment left behind, after a Wine was made in the

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the manner of the preceding Experiment, and poured three or four times their Quantity of boiling Water upon them, so as to make a thin aqueous Mixture. Then we set the containing Cask, loosely cover'd, in a warmer Place than was used for the Wine, and found the Liquor, in a few Weeks time, became a clear and sound Vinegar; which being drawn off from its Sediment, and preserved in another Cask, well stopped, continued long perfect and fit for Use.

21. This Experiment shews us a cheap and ready Way of making Vinegar from refuse Materials; such as the Husks of Grapes, decayed Raisins, the Lees of Wine, Grounds of Ale, Beer, &c. which are frequently thrown away as useless. Thus in many Wine Countries, the *Marc*, Rape, or dry Pressings of the Grapes are thrown in heaps, and suffered to putrefy unregarded; tho' capable of affording as good Vinegar, as the Wine itself would make. In some places they bury Copper-Plates in these Husks, in order to make Verdigrease: but this Practice seems chiefly confined to the Southern Parts of *France*. Our present Experiment shews us how to convert them to another Use; and the Direction extends to all the Matters that have once undergone, or are fit to undergo, a vinous Fermentation; for all such Matters will afford Vinegar. Thus all our Summer-Fruits in *England*, even Black-berries; all the refuse Washings of a Sugar-House, Cyder-Pressings, or the like, will make Vinegar, by means of Water, the open Air, and Warmth.

22. The whole Process, whereby this Change is effected, deserves to be attentively consider'd. And first, the Liquor to be thus changed, being kept warmer than in vinous Fermentation, in a few days begins to grow thick or turbid, and without throwing up Bubbles, or making any

any considerable Tumult, as happens in vinous Fermentation, deposits a copious Sediment. The Effect of this Separation begins to appear first on the Surface of the Liquor, which gathers a white Skin that daily increases in Thickness, till at length it becomes like Leather; and now, if it be continued longer in this State, the Skin turns blue, or green, and would at last grow solid, and then putrefy: therefore in keeping down this Skin as it grows, and thrusting it gently to the Bottom of the Vessel, consists much of the Art of Vinegar-making, especially from Malt.

Larger Observation.

23. It is to be particularly observed, that, if the Wine of our first Experiment were not bunged down when arrived at its vinous State, but suffer'd still to remain open and exposed to a warm Air, it would spontaneously become Vinegar; and the sooner, if a somewhat greater Degree of Heat, than served for the Making of Wine, were employed. Whence we might have used the Wine of our first Experiment for this Purpose, instead of adding Water to the Husks and Sediment, or Lees; but we chose the latter Way, to shew that even such refuse Matters will afford Vinegar; and again, to intimate how far the Art of Vinegar-making may be still improved, both in *England* where they brew a Wort from Malt, and in some Wine-Countries where they make their best Wines into Vinegars.

24. What we would chiefly observe, for the present, is, that *acetous Fermentation* requires a stronger Heat than the *vinous*; and that Wines having once finished their Fermentation, as Wines, do not naturally stop there; but, unless prevented by the Care of the Operator, proceed directly on to *Vinegars*; where again they make

no

no Stop; but, unless prevented here also, spontaneously go on to Vappidity, Ropiness, Mouldiness, and Putrefaction. From which larger Observation we would deduce this Axiom: That, to speak philosophically, *the Intention or Tendency of Nature is, to proceed from the very Beginning of vinous Fermentation, directly, in one continued Series, to Putrefaction, and thence again to a new Generation*; which appears to be the grand Circle wherein all natural Things are moved, and all the Physical, or rather Chemical, Phænomena of the Globe produced.

25. And hence we see how, by the Interposition of Man, this general Process of Nature may be stopped at different Periods, with different Views; so as to procure to ourselves Wines, Vinegars, and, as will appear hereafter, * particular Salts and Oils.

26. Another Corollary from the larger Observation above laid down, is, That the Word *Fermentation* has been usually applied to signify only a small Part of this grand Operation of Nature. Thus one limits the Word to the Production of Wines; another, to the Production of Wines and Vinegars; and some would distinguish it from *Putrefaction*: whereas either the Term *Fermentation*, or some other, should be made general, and denote the *Genus*, or *universal Operation*, whereof *Vinification*, *Acetification*, and *Putrefaction*, are only Species. At least we should thus attempt to follow and express Nature, in the Facts that are observed, and not proceed, in an arbitrary, narrow, or inadequate Manner, to impose Terms, and dress out Nature according to our particular Hypotheses and Conceits. But the Observation itself, on which

* See below, *Exp. VI. VII.*

this Doctrine is founded, being of moment to the right Understanding of the whole Affair of Fermentation and Putrefaction, we proceed to illustrate and confirm the last Part of it by an Experiment, as the two former Parts have been already *a*).

EXPERIMENT III.

That Wines and Vinegars, or all fermented vegetable Juices, have a natural Tendency to Putrefaction.

*Vapidity
and Putre-
faction suc-
ceed Fer-
mentation.*

27. We took a Gallon of thick, muddy Vinegar, produced after the Manner of our second Experiment, and letting it stand open, in a hotter Place than was required to make it Vinegar, it became in a few days a vappid, nauseous, and putrefied Liquor, throwing up a large Quantity of a dry powdery Substance to the Top, and depositing a less Quantity of a grosser Matter at the Bottom; soon after which the Body of the Liquor became clear again.

28. We might shorten the present Experiment, and save the Trouble of making either a Wine, or a Vinegar, to shew it. For if a Quantity of *Must* were set in an open Vessel, in a hot Stove-Room, where the Air had free Access, the Work would soon be performed, and the putrefied Liquor be produced almost at once, without stopping at the State either of Wine or Vinegar; according to the larger Observation deliver'd above *b*).

*Physical
Use of the
Experi-
ment.*

29. The present Experiment has a considerable philosophical Use, as affording Light to the Understanding, and leading us far into a Knowledge of our Subject. And (1.) it gives us the physical Reason why Wines and Vinegars,

a) See Exp. I. II.

b) §. 24, 26,

unless

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unless made exceeding strong, will not keep, but corrupt and putrefy, in hot Countries. For the Heat being there so great, as to keep the lighter feculent Parts of those Liquors suspended for some time in the Body of the Liquor, Corruption (which proceeds from a tumultuary Motion of all the different Parts of a compound Body together *a*), necessarily ensues.

30. (2.) Hence also we learn the physical Reason why Wines and Vinegars require to be racked from their Lees, in order to preserve them sound, or keep them from running into Putrefaction, to which we find they are strongly inclined; the Tendency of Nature being ever constant in urging them to that State. And the Case appears to be much the same in animal, and even mineral Substances; as we shall see hereafter *b*).

*Practical
Oeconomical
Uses.*

31. (3). This Experiment, therefore, furnishes us with a Rule for preserving vegetable Liquors from the last Stage of Fermentation, that is, Putrefaction or Corruption; *viz.* by first clarifying, and afterwards securing and defending them from the open Air, and too much Heat. Thus, for example, we can preserve the natural Juices of Quinces, Oranges, Lemons, Plants, &c. sound and uncorrupt, by first clearing them of their grosser Parts by the Filtre; or in some Cases by Boiling and common Straining; then putting them up in Glasses, pouring Oil on the Top, and setting them in a cool Place. And in the same Manner we find some of the more delicate and curious Wines are long preserved sound and sprightly: for the grosser Feculencies being first removed, the Oil poured on the Top prevents the external Air from entering; and by keeping the Glasses

a) See §. 27. and hereafter *Exp.* VI. and VII. See also the Lord Bacon's *Sylva Sylvarum* *passim*.

b) *Exp.* VII. VIII.

from the Sun, or open Day, too much Heat does not come at them.

*Physical
and Che-
mical Use.*

32. (4) It is here remarkable, what a large Quantity of solid, earthy Matter is naturally contained in all fermentable Liquors. Thus, if a pellucid Solution of the finest Sugar in Water be exposed to vinous Fermentation, it soon grows turbid, throws an earthy Skin to the Top, and deposits much terrestrial Matter at the Bottom in the Form of Lees. If the Wine be now drawn off clear and exposed to acetous Fermentation, here again it throws off much terrestrial Matter, both in the Form of a Skin at Top, and of Lees at the Bottom. Thirdly, if transparent Vinegar be exposed to putrefactive Fermentation, here again it separates a considerable Quantity of Earth, both at the Bottom and at Top. All which shews that the Separation of a gross Matter is essential to these several kinds of Fermentation, and that a copious Earth may lie concealed in fermentable Juices, and transparent Fluids, till it finds an Occasion of manifesting itself to the Senses.

*The Chan-
ges produ-
ced by Fer-
mentation.*

33. Before we proceed to animal and mineral Fermentation, it is proper to examine what are the Changes wrought upon vegetable Subjects by vinous and acetous Fermentation. This we may find, in some Measure, by comparing Must, or a bare Solution of Raisins in Water, with the Wine and Vinegar which the same Must, or Raisins and Water afford, in Vinification and Acetification; and in this Light they may be compared by the bare Use of the Senses: but their internal and essential Differences will better appear by a chemical Analysis, or Distillation.

34. Must, or a Solution of Raisins in Water, which makes a Kind of *Must* corresponding to the natural Juice of the Grape, is a sweet, clammy

my and somewhat odorous Fluid, which being committed to Distillation affords not the least inflammable Spirit. But after having passed thro' the Course of vinous Fermentation, it acquires several Properties it had not before. For example: it is more transparent and thin; loses of its Sweetness; has some Degree of Acidity and Roughness; proves more odorous, and affords a large Proportion of *inflammable Spirit*; as appears by the following Experiment.

EXPERIMENT IV.

That vinous Fermentation produces an inflammable Spirit.

35. We took three Gallons of new Wine, procured from Raisins and Water in the manner of our first Experiment, and committed it to the Alembic or Still, which being made to work gently, till the Liquor that came over, being thrown upon the hot Still-Head, would no longer take Fire by applying the Flame of a Candle to the rising Vapour, we thus obtained a considerable Proportion of *Brandy*, and a weaker *Spirit*. *Inflammable Spirit obtained.*

36. This Experiment shews us the common Method of making Brandies in Wine-Countries, or a Spirit from Malt, Melasses, Cyder, &c. in others. For the finest *French* and *Rhenish* Brandies, the Rums and the Arracks of the *Indies*, are obtained in the Manner of this Experiment; all of them being usually distilled a second time over, and *made up*, as they call it, with Water, or the weak aqueous Liquor of the second Running, as in our present Experiment, to a certain Strength, or supposed Standard, termed *saleable Proof*. *Use of the Experiment.*

*Proof in
Spirits
what.*

37. This *Proof* is judged of by the Head, or Crown of Bubbles, rising upon the Surface of the Liquor when shook in a long slender Vial, and by the Manner wherein these Bubbles vanish. For if they are too large and vanish too soon, the Spirit is deemed above *Proof*; if too small, and they go off too soon, it is said to be below *Proof*. But this is a fallacious Method of Judging; because there are certain known Ways of making a Spirit bear this Trial, when it is in Reality either above or below *Proof*. For the proper Meaning of the Word is, that a *Proof-Spirit* should contain about one half Water, and the other half Alcohol *a*).

*Philosophi-
cal Use.*

38. The philosophical Use of the Experiment is to shew, that an inflammable Spirit is produced by the Action of vinous Fermentation, from a vegetable Subject and Water, wherein no Signs of any such Spirit before appeared. In-
somuch that this may be justly esteemed the Criterion, or inseparable Effect, of *vinous Fermentation*.

*Spirit of
Wine how
obtained.*

39. The Ways of obtaining this inflammable Spirit, to the best Advantage, will be considered hereafter *b*). In the mean time it may be observed, that this Spirit being redistilled, so as to deprive it totally of its aqueous Part, is the *Spirit of Wine*, or Alcohol, whose dissolving Power was shewn, in the last Lecture upon *Menstruums c*); and this Method is the only one that is known of procuring it. For no Subjects but those of the vegetable Kingdom are found to af-

a) See this Matter farther explained in *Leç. XII. Exp. IV.*
See also *Leç. I. Exp. VII.*

b) *Leç. XI. and XII.*

c) See *Leç. VI. Exp. II.*

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ford it; and that only by means of a previous *vinous Fermentation*.

40. It should likewise be observed, that this *Alcohol* is one of the most essential Parts of Wine; so that, when it is withdrawn, the Wine loses its Nature; as we see by the Remains of the present Experiment. And when properly used, it is a certain Remedy for most Diseases incident to Wines; as keeping them sound and free from Corruption. Whence we have another Rule for preserving vegetable and animal Substances from Putrefaction. For this Liquor proves a kind of Balsam to them all, and is accordingly used, with Success, for preserving even animal Substances; as we see in anatomical Preparations, &c.

*The Use of
the Spirit
to Wine.*

EXPERIMENT V.

That acetous Fermentation abolishes the inflammable Spirit produced by vinous Fermentation.

41. We put a Quart of sharp Vinegar into a Glass Retort, and distilled, in a Sand-Heat, with Degrees of Fire, into a Glass Receiver, but found not the least inflammable Spirit come over; only an acid aqueous Liquor, commonly called *distilled Vinegar*; which, instead of burning, quenches Fire.

*Vinegar
yields no
Alcohol*

42. Hence it appears, that acetous Fermentation has a very different Effect from the vinous; and that the inflammable Spirit produced in the former, is either concealed, altered, exhaled, destroyed, or some Way abolished, in the latter. A part of this Spirit is unquestionably exhaled by the Heat employed in Acetification; yet Part also remains behind under a different Modification, so as to be recovered by Art in an inflammable Form; as we find by distilling the *Sugar of Lead*,

*Use of the
Experi-
ment.*

Lead, which is only Lead dissolved in Spirit of Vinegar.

43. Our Experiment affords us a Criterion of acetous Fermentation, as before we had of the vinous. For if an acid unflammable Liquor comes first over by Distillation from a vegetable Subject, previously fermented, this will determine that Fermentation to have been of the acetous Kind.

44. Thus, therefore, we are plainly led to allow of two very different kinds of Fermentation, in the same vegetable Subject; and we conceive that some other Species may be found upon due Enquiry.

EXPERIMENT VI.

That vegetable Matters turn of an animal Nature by a hot Fermentation, or Putrefaction.

Putrefaction in Vegetables. 45. We took a large Quantity of fresh, green Cabbage-Leaves, and pressed them hard down with Weights in an open Tub, bored full of Holes on the Sides and set in a warm Place. By standing in this State for some Days, the Leaves conceived a Heat in the middle, which spread to the more external Parts, till at length nearly the whole was converted into a pappy, putrefied Substance, whose Consistence would not well suffer it to separate into a thicker and a thinner Part. This Substance being distilled in a Glass Retort, afforded the same Kind of volatile Salt and Oil, as if it had been an animal Substance.

The Experiment extended. 46. This Experiment is general, and succeeds alike in all tender, juicy, vegetable Subjects; so that both the acid and alkaline Tribe of Plants, the sweet and the bitter, the astringent, and emollient, &c. resolve into this same pappy, putrefied

treified Substance. We observe it also in Hay that is stacked wet; in Horse-litter thrown on Heaps; in the Grape-Husks, or Apple-Pumice, after pressing for Wine or Cyder; and the larger the Heap, and the greater Weight the Matter sustains, the greater the Heat; provided the Access of the Air be not prevented.

47. Hence we see the Way employed by Nature *In Use.* for changing all *vegetable* into *animal Substances*, or of reducing the Matters of both Kingdoms to a Similarity; so that the one may be used for several Purposes instead of the other. And thus Nature annually makes large Quantities of Compost, from the refuse Weeds, Leaves, Trash of the Fields, Woods, and Gardens; for this vegetable Matter thus putrefying, and becoming soft and pulpy, is easily diluted by the falling Rains, and thence dispersed over the Face of a Field, and carried into the Pores of the Earth. And thus the Chemist may, by Distillation from such putrefied vegetable Subjects, procure volatile Salts and volatile Spirits, hardly to be distinguished from those of Hartshorn, &c. at least the volatile Salt and Spirit so obtained might serve together with Sea-Salt, for making of Sal-Ammoniac *a*). For it appears that the Matter of the fixed Salt in Vegetables is, by this Operation, truly volatilized. Whence not a Grain of fixed Salt can be procured from the largest Quantity of this putrefied Matter, provided the Operation were compleatly performed.

48. This Experiment has various Uses, not only in Trades, but also in natural Philosophy and Medicine. And first, it shews an artificial as well as natural Method of converting any, or all of the different Subjects of the vegetable *In Trade.*

a) See *Let. XX. Exp. I.*

Tribe into the same undistinguishable Substance, totally destroying all the specific Differences which before discriminated that great Variety. And the same Observation reaches also to animal Bodies, as we shall see hereafter *.

In the animal Oeconomy.

49. It also throws considerable Light upon the Process of animal Digestion, as performed in the Stomach and Intestines; it shews us the Nature of Gangrenes, Mortifications, and carious Bones in the Body; and the physical Reason why no fixed Salt is found in the Blood, Bones, or Flesh: All which Particulars may be farther illustrated and confirmed, by considering the like Process in an animal Subject.

II

EXPERIMENT VII.

That animal Bodies naturally undergo a Fermentation, or Putrefaction, after Death.

Animal Putrefaction.

50. If any large animal Body, as that of a Horse or a Dog, for example, be exposed in a dead State to the open Air and the Summer's Sun, it begins in a few Days to swell, purge, and emit a nauseous Stench. At length the Form of the Carcass is destroyed by the Commotion, and resolved into a putrid, fetid, stercoraceous Matter; a large Part in the mean Time flying off into the Air, so as to leave but a small Proportion of a mucilaginous, pappy Substance, which soon grows dry, or turns to a Kind of Earth. But a Quantity of this Matter being collected before it grows dry, and distilled, it is said to afford the burning *Phosphorus*, as putrefied Urine is known to do.

* *Exp. VII.*

51. This

Of Fermentation and Putrefaction. 137

51. This Experiment or Observation is universal, and holds equally of Birds, Beasts, and Fish. Whence Rivers, the Ocean, and the Atmosphere itself, must necessarily be impregnated with fermenting, putrefying, and putrefied Particles, which mixing with other Matters, and being dispersed through the immense Bodies of those Fluids, they undergo therein such Changes, whether by uniting with the Salts of the Air and Ocean, or otherwise, as prove not unfrequently destructive or noxious to the Creatures that inhabit those Elements. For this putrefied Matter appears to be in itself a Kind of Poison, infecting the Air wherein it spreads; so as to occasion pestilential Diseases near the Places where great Battles have been fought, when the unburied Carcases of the Slain thus resolve and go off into the Atmosphere. Many other Instances we have of the poisonous Nature of putrefied animal Substances, in rotten Eggs, mortified Flesh, and the like: whence this seems to be another particular Species of *Fermentation*.

52. It has been disputed, whether there be a real Fermentation in the present Case. But supposing this not to be a Dispute about Words, it should seem that there is a proper Species of Fermentation, peculiar to animal Subjects, as there is one peculiar to Vegetables. Till this Point be settled, we should not lay down vegetable Fermentation, as the Test and Standard of Fermentation in general, and so judge of all other Kinds according as they approach to, or recede from, this Standard. For want of distinguishing in this Case, all true Fermentation seems denied to the Blood and Juices, circulating in a living animal Body, as well as to the Sap of Vegetables. But were the Enquiry into Fermentation prosecuted in its full Latitude, and not arbitrarily

arbitrarily confined to any single Species, perhaps many natural and artificial Operations would prove to be actual Fermentations. To say that there is no Fermentation in the Blood, because it affords no inflammable Spirit upon Distillation, is in effect the same as to say that Blood is not Wine. Whereas the Question is not whether there be a *vegetable Fermentation* in the Blood, but whether there be not an *animal one*; the Criterion whereof is the Production of a volatile urinous Salt, as the Production of an inflammable Spirit is the Criterion of vinous Fermentation.

*Chemistry
of Nature
in Bodies.*

53. And here is a Door opened for enquiring into the Chemistry of Nature, as it is exercised in the Bodies of Men; so as to discover the natural Means whereby vegetable Substances taken in at the Mouth, by the Way of Aliment, are prevented from running into vinous or acetous Fermentation; but are, on the contrary, changed into a balsamic, unctuous, and milky Liquor, or Chyle, that turns red in the Arteries, recruits the Blood, and nourishes the Body. For all this seems to be the Effect of a peculiar *animal Fermentation*, the Laws and Process of which are little considered. And in this View, the several Juices of the Body, as the Saliva, Bile, Pancreatic Juice, &c. may be regarded as animal *Menstruums*, acted upon, and made to act in the Body, by determinate Motions, for determinate Ends.

III.

EXPERIMENT VIII.

That there may be a Kind of Fermentation in mineral and metallic Bodies.

*Mineral
Fermentation.*

54. We took an Ounce of Lead and as much Bismuth, and melted them together in an Iron Ladle;

Ladle; then heating two Ounces of Quicksilver in another Ladle, we mixed all the three metallic Matters together as an Amalgam; which, when cold, appeared perfectly uniform or homogeneous, and totally passed thro' the Pores of Leather in a running Form. But this Mixture being suffered to cool, and stand quiet for some Hours, a gross Matter separated from it by Degrees, and floated upon the rest; which was left to thin and fluid, as to pass through Leather, leaving the gross metallic Matter behind.

55. Hence it should seem that even metallic Matters may have their peculiar Fermentations, as well as vegetable and animal Subjects. *The Experiment extended.* For when the present Experiment comes to be carefully considered, it appears to have all the Requisites of Fermentation. For here is, (1.) a fluid Form, (2.) an uniform Matter, (3.) an intestine Motion, and (4.) an actual Separation of a grosser Matter, leaving a thinner behind. All which Particulars we have found to hold in the several Species of Fermentation above examined.

56. There are many more Instances of an apparent Fermentation in mineral Bodies, one or two whereof it may be proper to mention. Thus, if an aqueous Solution of the common green Vitriol be exposed to the Air in the Summer-time, and kept continually supplied with fresh Water as the former exhales, the grosser metallic Part of the Vitriol will subside, and the rest gradually shoot upwards all round the Vessel, in Form of an unctuous, crusty Matter; till the whole Body of the Vitriol is thus successively so altered that the Part shot into the crusty, unctuous Form, will neither become Vitriol again, nor corrode any fresh Metal; and in all other Respects it appears a different Thing from Vitriol. And hence

hence seem to proceed the Complaints of the Makers of Vitriol, that in rainy, windy, and cloudy Weather, their Vitriol-Stones, which lie open to the Air, will not sometimes yield a solid crystalline Vitriol, but only an unctuous Matter. This may therefore appear to be a Fermentation in all its Forms, as being attended with a spontaneous intestine Motion, a spontaneous Separation of constituent Parts, and a remarkable Alteration of the Subject.

57. It also makes to the present Purpose that solid and hard Pyrites, or Vitriol-Stones, being exposed to the Air and moistened with Water, will, like a vegetable Subject *a*), grow hot, fume, and even take Fire, as was observed in our fourth Lecture, and afterwards afford Vitriol; a Thing very different from the Stones themselves *b*). So that, upon the whole, we may conclude, that in a proper Sense, there is an actual *Fermentation* exercised, not only in the vegetable and animal, but also in the mineral Kingdom.

V.

AXIOMS and CANONS.

1. All the Instances being duly considered, and a large View of Things taken in, we may define *Fermentation*, in general, a sensible internal Motion of the constituent Particles of a moist, fluid, mixed, or compound Body; by the Continuance of which Motion, those Particles are gradually removed from their former Situations, or Combinations; and again, after some visible Separation is made, joined together in a different Order and Arrangement. And thus the

a) See above, *Exp.* VI.

b) See *Leç.* IV. *Exp.* V.

whole Process of Fermentation consists of two different Operations, viz. an *Analytical* one, whereby the Particles are resolved, and a *Synthetic* one, whereby they are new ranged: So that whenever these two different Effects are found to be produced, in direct Sequence, with the Circumstances above described, we need not scruple to call the Operation by the Name of *Fermentation*, whether it happen in the Blood, or other animal, vegetable, or mineral Substances *a*).

2. That all separable, mixed, or compound Bodies may be the Subjects of this general Operation; but that the easier they are separable by Means of Water, Air, and Heat, the more readily they ferment *b*). Thus the sweet or saccharine Part of Malt, more readily dissolving in warm Water, ferments easier than unmalted Corn, which is more clammy and will not dissolve so soon. And hence the Flesh of animal Bodies putrifies sooner than the Bones. And this appears to hold in all Instances *c*).

3. That this general Fermentation is divisible into many distinct Species, particularly into *vegetable*, *animal*, and *mineral d*); the vegetable Kind again into *vinous*, *acetous*, and *putrefactive*; the vinous again into mucilaginous, mouldy, and putrefactive; and so of the acetous, &c. Whence we may deduce a *Canon* for adjusting all the different Species of Fermentation; which being once fixed might put an End to infinite hypothetical Disputes upon this Subject, and lead to farther Discoveries both in Nature and Art.

a) See the whole Lecture, *passim*.

b) See *Exp. I. VI.*

c) See *Exp. I. VI. VII.*

d) See the whole Lecture, *passim*.

4. That it is in the Power of Man to prevent, stop, and regulate these natural Operations at any assigned Point of Time. Indeed it is thus we come by our Wines and Vinegars; It is thus that Men discovered the Art of Embalming; It is thus we preserve many vegetable, and animal Juices, in their natural or unfermented State; It is thus we preserve Yeast, and Wine-Lees, Subjects extremely apt to putrefy; It is thus we can at any Time stop the Course of vinous Fermentation, and produce a sweet, or half fermented Wine; It is thus we cure the Frettings, or other Diseases of Wines; and thus we stop Mortifications in the Body, and Caries in the Bones. And most of the Artifices employed for these Purposes, depend upon a Knowledge and Regulation of the physical Causes and Instruments that produce the Change; which Causes and Instruments, as we above discovered, are chiefly, Heat, Moisture, and the external Air *a*).

5. That a saccharine Matter is the Basis of Wines, Vinegars, and inflammable Spirits *b*).

6. That a great variety of sound, perfect, and wholesome Wines may be made, in Countries that do not naturally afford Grapes, by a prudent Use of Sugar, or Raisins and Water *c*).

7. That the Matters called Ferments are of Use in beginning, regulating, and determining the Species of Fermentation *c*). Thus fresh Yeast determines the Fermentation of Wheat-Flour to make our common Bread, which would prove of another Kind, if the Flowers or Lees of Vinegar were used. And thus specific or de-

a) See the whole Lecture, *passim*.

b) See *Exp. I. §. 15. &c.*

c) See *Exp. I.*

terminate Ferments have their correspondent Effects. If Sugar, Honey, Manna, Treacle, or new Wine be added to Vinegar, themselves are soon changed into Vinegar, without stopping to make Wine; because the acetous Ferment, or Vinegar, over-rules them. And so Vinegar is soonest made in a Cask that has before contained the same Liquor. And if the best Wine were put into a Cask that had held putrefied Vinegar, the Wine would not now make Vinegar, but immediately run into Corruption. So great and so decisive a Power have specific Ferments; the Use whereof is therefore evident, and may afford considerable *Rules* in Chemistry, practical Philosophy, and Arts.

8. That the Degrees of Fermentation differ with the Degrees of Heat employed *a*). Thus we saw vinous Fermentation required a less Degree of Heat than the acetous; the acetous a less than the putrefactive; which latter may even consist with a Degree of Ignition *b*).

9. That a particular Kind of Fermentation may be carried on in the living Bodies of Animals and Vegetables, which are largely supplied with the requisite Instruments of Fermentation, *viz.* Water, Air, and Heat: And in Fact both Vegetables and Animals appear to have an intestine Motion in all their circulating Fluids, which continually deposite a grosser Matter in the Canals and Parts they move through. Whence, by our Definition of Fermentation *c*), this natural Act may be accounted a Species of Fermentation, producing a Change in the nutrimental Matter of Vegetables and Animals, and converting it into their own Substance.

a) See *Exp.* I, II, III, IV, V, VI.

b) See *Exp.* VI.

c) See *Ax.* I.

10. That when Vegetables or Animals die, there soon begins a different Kind of Fermentation in all their Parts; tending now not to the Repair, but to the entire Destruction, of their organical Vessels, the confused Mixture of their solid Parts and Juices, and a Volatilization of their whole Substance *a*).

11 That dry or solid Bodies cannot, in that State, undergo a proper Fermentation: for tho' they may in that State be separated into minute Particles, yet they cannot range themselves together in any new Order, nor deposite a grosser Part, without being agitated by some Fluid, or suspended therein for some Time. And hence, in over-heated Mines, the Ore is thus *analytically* destroyed, and cannot range itself into a metalline, or any other regular Order again, for want of the requisite Moisture or Fluidity; whence the Matter appears like a Heap of rotten Earth, or what the Miners call *Dead Metal b*); of which we have a remarkable Instance in the over-heated or fired Mixture of Sulphur and Iron-Filings *c*).

12. That the terrestrial, marine, and atmospheric Regions have each their proper *Fermentation*, different in Kind, and subdivisible into particular Species, whereby the Changes of all Bodies one into another are naturally performed *d*); And that in Imitation hereof, by a thorough Knowledge of the natural Agents that produce these grand Effects, Art likewise may produce extraordinary Changes in Bodies *e*).

a) See *Exp. V. VI.*

b) See *Exp VIII.*

c) See *Lect. XIX Exp. III.*

d) See the preceding *Lectures* upon the *Elements*. See also that upon *Mensstruums*, and the several Experiments in the present *Lecture*.

e) See *Lect. I. passim.*

LECTURE VIII.

CONTAINING

Analytical Chemistry; or, the Art of Analyzing Vegetable, Animal, and Mineral Substances, and resolving them into different Parts or Principles.

I.

1. **T**HE whole of Chemistry may be comprehended under the Art of resolving Bodies into their Principles, and of composing new Compounds from those Principles, by Means of the common Elements, Fire, Air, Water, Earth, and particular *Menstruums*. We shall accordingly in our present Lecture, endeavour to enquire into the Business of chemical Resolution, in the vegetable, animal, and mineral Kingdoms, with a View to discover what useful *Principles* may be thence obtained; intending, in our next Lecture, to consider the correlative Business of Composition: so that the two together may contain a summary Account of the Nature, Office, and Use, both of analytical and synthetical Chemistry; of which the one takes Bodies to Pieces, or reduces them to their component Matters, and the other, by putting these Matters or different Pieces together again, in various Manners, forms a large Set of new Productions, that would be unknown to Nature without the Interposition of Art. And such Productions, for Instance, are, *Brandy, Soap, Glafs, &c.*

2. But before we enter upon the Enquiry itself, it is necessary we should distinctly explain

L

what

Principles
what.

what we mean by the Word *Principle*, about which many Disputes have been raised. We must therefore observe, that the more intelligent among the modern Chemists do not understand by *Principles* those original Particles of Matter, of which all Bodies are by the mathematical and mechanical Philosophers supposed to consist. Those Particles remain undiscernible to the Sense, tho' assisted with the most finished Instruments; nor have their Figures and original Differences been determined by a just Induction. Leaving, therefore, to other Philosophers the sublimer Disquisition of primary Corpuscles, or Atoms, of which many Bodies and Worlds have been formed in the Fancy, genuine Chemistry contents itself with grosser Principles, which are evident to the Sense, and known to produce Effects in the Way of corporeal Instruments. And these grosser Principles are every Way sufficient to answer the Purposes of philosophical Chemistry, which consists wholly in Experiment, and the Explanation of Facts and sensible Operations. Where, by the Way, it may be observed, that Chemistry is an Art extremely well suited to the Nature of Man, as it requires nothing more than the Use of such Faculties as he evidently finds himself possessed of. But when once we leave the Oracles of Sense, and introduce metaphysical Speculations and Notions into Chemistry, it then becomes a corrupt Fountain of Hypothesis and Illusion. To rectify Chemistry, therefore, the Rule is to keep close to the Information of our Senses, the Laws of Induction, and the Use of material and sensible *Principles*.

3. These sensible Principles, so far as we know them, are significantly expressed by the common Words, *Water, Earth, Salt, Sulphur, and Mercury*: to which might be added the Air, if a Way were

were known to fix it, so as to render it more sensible, tangible, and corporeal *.

4. By *Water* we understand a sensible, transparent Liquor, without Taste or Odour; that freezes with a certain Degree of Cold, and liquifies from that State with a certain Degree of Heat; that extinguishes Fire, &c. By the Chemists this is otherwise called *Pblegm*.

5. By *Earth* we understand an insipid, dry, powdery Substance, that will neither dissolve in Water, nor burn away in a strong Fire; but, with the Addition of fixed Salt, melts into Glass.

6. By *Salt* we understand any sensible Body that readily dissolves in Water, tastes sharp or pungent upon the Tongue, and has a great Disposition to unite with Earth, so as to appear in a solid Form; as in common Salt, Alum, &c.

7. By *Sulphur* we mean any Matter that will readily burn and disappear in the Fire, and that will not easily, or of itself, mix with Water.

8. And lastly, by *Mercury* we understand a sensible Body that has the Fluidity, Gravity, and Appearance of common Quicksilver.

9. We do not lay down these as adequate Definitions, but only as sensible Marks whereby the Things meant may be readily known and distinguished for ordinary Use. Just Definitions can be drawn only from a full and perfect Discovery of the Nature and Properties of Bodies, which we are far from knowing; nor do we usually meet with any of these Principles in a pure and perfect State, unmixed with other Bodies. When they appear to the Senses to be thus far purified, they are the Principles we mean, or what we

* See Lect. III. Ex^t. X.

emphatically call the *Chemical Principles*; tho' they may be every one of them destructible, as to that Form: but then they cease to be chemical Principles.

10. And thus we have endeavoured to settle the chemical Meaning of the Word *Principles*, and to lay down Marks or Criteria for discovering and distinguishing them, when we meet with them hereafter in the following Experiments.

11. These Experiments we shall endeavour to make as general as we can, and give an Example in each of the three Kingdoms, as they are called, viz. the Vegetable, Animal, and Mineral.

EXPERIMENT I.

That Vegetables are resolvable, by Fire, into four of the chemical Principles, viz. Water, Oil, Salt, and Earth.

Worm-wood analysed.

12. We took two Pounds of common Worm-wood cut small, which we put into a Glass Retort in a Sand-Heat, and distilling with Degrees of Fire, and a frequent Change of Receivers, we obtained (1.) an aqueous Liquor, and (2.) an Oil. Then taking out the Remainder, and burning, or calcining it, in the open Air, it turned to a grey Kind of Ashes; which being boiled in fair Water communicated thereto (3.) a Salt. This Salt we obtained in a dry Form, by letting the Solution stand at Rest for some Time, then decanting the clear Liquor, and exhaling the superfluous Water. And (4.) we found an earthy Substance remaining at the Bottom of the Water wherein the Ashes were boiled.

The Experiment made general.

13. This Experiment being well attended to is very instructive, and shews that the *chemical Principles*

Principles above-mentioned are not imaginary or fictitious Things; but Things palpable, and evident to the Senses. For here we have a Water, an Oil, a Salt, and an Earth, all afforded us by a vegetable Subject. And the Experiment may be made general without much Variation: for all the vegetable Subjects hitherto examined, in this Manner, resolve themselves into the same general Principles, which differ only (1.) in Respect of the Kind of Salt; that being in some more volatile, in others more fixed; in some acid, in others alkaline; and (2.) in the Nature or particular Properties of the Oil; which in some Plants is thinner and more fluid, in others more gross and viscous; &c. But all the Principles thus obtained agree to the general *Definitions* above laid down*. So that there appears to be no Vegetable in Nature, but what is thus resolvable into Water, Oil, Salt, and Earth.

14. To obtain these Principles pure, we must *The Water* (1.) separate all the Oil that may chance to re-^{*purified.*}main suspended in the *Water*. This is effected, in a considerable Degree, by the Filtre; which being kept continually filling up, so as that the lighter Oil may not come in Contact with the Paper, the aqueous Part is thus transmitted tolerably free from Oil. (2.) But still there may remain some small Proportion of oily and saline Matter therein? If the saline Matter be acid, the way to destroy it is, to mix a little Chalk, or any pure and fixed alkaline Salt, with the Liquor. By this means also more of the Oil will be set free; so that being now filtered again, and gently distilled with a soft Heat, the aqueous Part will rise much purer, and pass for Water in the Judgment of the Senses. (3.) If the Plant

* Sect. 4—8.

was alkaline, and an alkaline Salt abound in the aqueous Liquor, let it be made neutral with one that is acid; and thus again the Water may be separated pure, by means of the Filtre and Redistillation. And this is the Method of manifesting to the Senses, that the chemical Principle *Water* is naturally lodged in, and may be separated from all vegetable Substances*.

*The Oil
purified.*

15. In order to procure the *Sulphur*, or oily Principle, pure, the unctuous Matter, obtained by this general Process, may be washed from its adhering Salts and grosser Earth in warm Water, barely by shaking them in a Glass together, and then separating the Oil from the Water by means of the common separating Glass; where, if the Oil be specifically heavier than Water, it sinks to the Bottom, and may be suffer'd to run out first; if specifically lighter, it floats a-top, and may by the Finger applied to the Bottom of the Glass, or some other Contrivance, be kept behind, when all the Water and feculent Parts are run from it.

*The Salt
purified.*

16. To obtain the saline Principle pure; (1.) if it be of the volatile urinous Kind, the Matter may be dissolved in Water, and made to pass the Filtre; then set in a gentle Heat to sublime: for it will thus rise and leave the Water behind, as being much more volatile than that. (2.) If it be required still purer, the best Method hitherto known is, to sublime it from finely pulverized Chalk; then to saturate it with a clean Spirit of Sea-Salt, so as to convert it into a true Sal-Ammoniac; which being mixed with Salt of Tartar, and again set to sublime, the volatile Salt will rise highly purified, so as long to retain its Whiteness. (3.) But if the saline

* See *Lect. V. Exp. I.*

Matter obtained be of the fixed Kind, the Method of purifying it is, to dissolve it in fair cold Water; suffer the Solution to subside; then decant the clear Liquor, and evaporate it in a clean Iron Pan or Glass Vessel, constantly stirring it, till it becomes dry and white: (4.) Or to purify it still farther and render it perfectly white, let it be put into a clean Crucible, and exposed for a while amidst the Flame of burning Charcoal, but without Melting it.

17. Lastly, to obtain the earthy Principle in *The Earth* its Purity, let it be thoroughly calcined, boiled *purified.* in several Waters, in order to get out all its Salt; then dry it over a clear Fire, or in the Sun. And if these several Operations be performed in Perfection, we then obtain what we properly mean by the *chemical Principles of Vegetables.*

18. And tho' it be not always necessary for the Purposes of Chemistry, or the common Calls of Life, to bring these Principles to the Degree of Purity here mention'd, yet there are many Cases that absolutely require them to be so purified; otherwise the Operations in which they are employed may easily miscarry: and this we desire may be noted as one considerable Reason of the Failure of particular Experiments and Operations, both in Chemistry itself, and in many of the chemical Arts; particularly the Art of Glass, Distillation; &c.

19. The Uses of this leading Experiment are *Uses of the* numerous; we shall touch upon a few of them. *Experi-* And first, we may learn from it that these chemical Principles are found in different Quantities in different Vegetables, or in the same at different Seasons or Times of Growth. Thus, for instance, Olives, Almonds, Mace, &c. contain such an Over-Proportion of Oil, to the other

Principles, that it may be copiously got from them barely by Pressure. The Vine in the Spring affords a larger Proportion of fixed alkaline Salt than at any other Season; and the same holds of the Wood usually burnt for Pot-ash. And thus we find that the aqueous and saline Principles preside in Vegetables in the Spring, but the oily in the Summer and Autumn; that all young Plants abound more with Water, than such as are full grown; and that Oil is most plentifully contained in the oldest Trees, and those of the colder Climates. Whence we are directed to the proper Times, Seasons, and Places for felling the Timber designed for Pitch, Pot-ash, Fewel, and Charcoal.

20. By applying this Experiment to different Vegetables it has been found, that Vegetables are naturally distinguishable into two grand Tribes, *viz.* the Acid and the Alkaline; the first affording a volatile Acid, and the other a volatile Alkali, upon dry Distillation. Thus Guaiacum, Cedar, Box, Cinamon, Cloves, Sorrel, Mint, Baulm, &c. afford an Acid; but Garlick, Leeks, Onions, Horse-radish, Scurvy-grass, Mustard, &c. afford an Alkali; which, when rectified, is hardly distinguishable from that of animal Substances, so as nearly to resemble the Spirit and Salt of Hartshorn *a*).

21. This Experiment also shews us the Methods of making or procuring Tar, Charcoal, fixed Salt, and elementary Earth, from Vegetables; four capital Things in Arts and Trades. Tar is the scorched Oil of unctuous Wood, forced out by Fire, as the gross Oil is in the *present Experiment b*). Charcoal is Wood burnt close

a) See *Let. VII. Exp. VI.*

b) See also *Let. II. Exp. III.*

to Blackness *a*); Soap, a Mixture of fixed Salt and Oil; Glass, a mixture of Earth and fixed Salt; and elementary Earth makes all the Tests and Coppels for refining of Gold and Silver.

22. Again, the present Experiment shews us the Nature of vegetable Fumes, by which, in the Way of animal Curation, Fish and Flesh are long preserved, free from Putrefaction or Corruption. For where-ever green Wood, or any acid vegetable Matter is burnt, the acid Particles rise with the Smoke, and in this Form penetrate and lodge in animal Substances exposed thereto; so that this Smoke acts upon them in the same Manner as the Fume of Spirit of Sea-Salt or Nitre would do. And whether it be not a nitrous Acid which thus tinges the Hams, Herrings, &c. red in drying, we recommend to farther Examination.

23. Our Experiment also confirms what was before observed *b*), that the Force of Fire is not sufficient to reduce a vegetable Substance to Ashes without the Help of the Air, and that so long as the fixed Oil, which causes the Blackness, remains in a vegetable Coal, it will afford no fixed Salt by Decoction in Water *c*). Whence for making Pot-ash, and all the fixed Salts, to Advantage, we have this Rule, thoroughly to calcine the Subject, so as to leave no fixed Oil behind.

24. And hence we are also instructed in the physical Nature of a vegetable Coal, and see how it may have such considerable Effects upon Metals, in the Way of a *Flux*; since we find it contains a fixed Oil, firmly united to the Matter of a fixed Alkali; whence, to use this Coal as a Flux, is the same Thing as to use a fixed Salt

a) See also *Let.* II. III.

b) *Let.* II. *Exp.* IV.

c) See *Let.* II. *Exp.* IV.

intimately united with a fixed Oil, which operates powerfully upon Ores, as we have formerly shewn *. And so much for the *Analysis* of Vegetables.

II.

EXPERIMENT II.

That animal Matters are resolvable, by Fire, into the four chemical Principles, Water, Oil, Salt, and Earth.

Bone analysed.

25. We took four Pounds of animal Bones, that had been well boiled to get out their Marrow or Fat, and then thoroughly dried again; and breaking them into small Lumps, we put them, dry as they were, into an earthen Retort, luted on a Glass Receiver, and distilled, with Degrees of Heat, in a naked Fire. There first came over in Drops an aqueous limpid Liquor, which we reserved apart, by changing the Receiver. Then increasing the Fire there came over white Fumes, a volatile Salt, and a Quantity of Oil. The Vessels being suffered to cool, we found the Bones turned black in the Retort; but being calcined in a naked Fire, with the Admission of the free Air, they turned to white Ashes. Then boiling these white Ashes in Water, we found by Evaporation that they communicated no fixed alkaline Salt thereto.

The Experiment extended.

26. This Experiment is general, or succeeds, with little Variation, in all other animal Subjects, whether they be Flesh, Blood, Serum, Fish, Birds, Snakes, the Whites of Eggs, Horn, Hair, Hoofs, Silk, or the like; the principal Difference being only, that these Substances

* See *Lect. I. Exp. III.* See also hereafter the Lectures upon *Mineralogy* and *Metallurgy*.

respectively

respectively contain more or less Earth, Water, Salt, and Oil. Thus Blood being distilled in its natural State, or as it is drawn from the Vein of a healthy Person, will yield about seven-eighths of its Quantity in Water. And if any animal Subject be not well purged of its Oil, by boiling in common Water, before it is committed to Distillation, it thence affords a greater Quantity of a burnt empyreumatical Oil, that strongly taints and impregnates the volatile Salt and Water, with a nauseous Scent and Taste; which are hard to get rid of, even by repeated Rectifications.

27. The Principles separated by the present *its Uses.* Experiment appear to be, in general, the same with those before gained from a vegetable Subject. They may be separately purified and made elementary, after the same Methods as we there laid down. And thus, by comparing the Productions of both Processes together, we shall find that we have a Water, an Oil, a Salt, and an Earth in both Cases.

28. The two Waters seem scarce to differ, when reduced to the same Degree of Purity; no more do the Oils and the Earths; but all the Salt in the present Case is volatile; the Ashes containing no fixed Salt at all: whence this appears to be the principal chemical Difference betwixt vegetable and animal Subjects, that the vegetable Kind yield a fixed Salt by Calcination, and the animal Kind, one that is volatile by Distillation. But this holds only of the acid Species of Vegetables; for the alkaline Species yields little or no fixed Salt upon Calcination. So that betwixt the alkaline Tribe of Vegetables, and the whole animal Kingdom, there seems to be little Difference; either in this, or any other chemical Respect *. But tho' some Difference

* See *Let.* VII. *Exp.* VI.

should

should be found betwixt the animal and vegetable Oils, as there is thought to be in the Making of Soap, and some other Instances; yet the Principles of animal and vegetable Subjects may be justly reputed the same, as both equally agree to our general Definitions of Water, Oil, Salt and Earth *a*). But when the several Principles of Vegetables and Animals are reduced to the same Degrees of Purity and Fineness, there seems, so far as our Trials have gone, to be no sensible Difference between them. Thus the pure elementary Earth of Vegetables serves for the making of Tests and other Purposes, as well as the elementary Earth of Animals; solid Soap is made of vegetable Oils, as well as of animal Fats; and the volatile Salt of alkaline Vegetables, or even of acid Vegetables when putrified, is not to be distinguished from the volatile Salt of Animals, when both are thoroughly purged and purified.

The animal Principles how purified.

29. But the Labour and Difficulty required, to bring these Principles to a high Degree of Purity, has proved a chief Cause of their being thought different; for we see that the Oil tenaciously adheres to the volatile animal Salt, and thus adds some Qualities that do not properly belong to that Salt. But if a volatile animal, and a volatile vegetable Salt, be each separately converted into Sal-Ammoniac, by Means of Spirit of Sea-Salt, no sensible Difference can be found betwixt them. And thus, if a vegetable Oil and an animal Oil were equally purified, subtilized, and freed from all the Matters that do not essentially belong to them, they would not sensibly differ. At least, this seems confirmed by several Experiments *b*).

a) See above, §. 4 — 8.

b See Dr. Cox's Papers in the *Philosophical Transactions*.

33. And hence may some Advantages be derived to Arts and Trades, by making the Subjects of one Kingdom serve for those of the other, where the one is cheaper than the other. Thus, as we before observed *, a volatile Spirit and Salt, like those of Hartshorn, may be drawn from the alkaline Species of Vegetables, and all putrefied Plants; at least from Bones, purged of their Fat by boiling in Water. *Farther Uses.*

31. The present Experiment has many other Uses and among the rest remarkably shews how a perfectly dry, insipid, scentless, and solid Body may yield a great Variety of Tastes and Odours, barely by being applied to the Fire. For the impure Water, the volatile Spirit, the Salt and the Oils, have each a particular Taste and Odour. And tho' the Subject itself were fixed, we see it nevertheless affords several volatile Matters. And as this fixed Substance was originally composed of a fluid Matter, we are hence taught that the animal Solids and Fluids have the same common Nature; their Difference consisting only in a greater or less Proportion of Water and Earth. For Blood, upon the like Analysis, affords more Water and less Earth than Bone.

32. This Experiment likewise shews us that a Bone may be entirely divested of its Water, Salt, and Oil, without losing its pristine Figure and Dimensions. For after those Principles are separated from it, the elementary Earth, tho' absolutely dry and friable, still hangs together in the natural Form and Figure of the Bone; which thus remains exhausted of all that Matter, which the Fire was able to carry off, without affecting the elementary Earth itself.

* See *Let. VI. Exp. VI.*

Whence we evidently see that the Use of this elementary Earth, in vegetable and animal Bodies, is to afford a Lodgment, a Support, or Skeleton to the other Principles, which are much more diffipable and destructible than itself.

33. And as our Experiment succeeds alike in all animal Matters, and even in the Jelly obtained from a Bone by long Boiling, till the elementary Earth is elixated, or drained of the other Principles; we hence learn that the Matter of these other Principles proceeds only from the Juices of the Body, where, as well as in the Jelly, they appear in an almost insipid and inodorous State, yet are capable, by Distillation, of affording Substances so highly sapid and odorous, as we find the volatile Salt and Oil to be. Whence this Conclusion naturally follows, that these Principles did not exist in a volatile State in the Body, as requiring even a greater Degree of Heat, than that of boiling Water, to separate them.

34. We may farther observe that the present Experiment affords us the most volatile Substance hitherto known; for well-purified animal Salt is more volatile than Spirit of Wine, and rises in Distillation before it. Hence this Salt readily evaporates in the open Air, and being laid upon the Palm of the Hand goes off insensibly, without any Effect; tho' if it were pressed close to the Skin, by a sticking Plaister, it would prove corrosive; and in this Manner it is sometimes used, for making Issues in Children, instead of the stronger Causticks.

III.

EXPERIMENT III.

That certain mineral or metallic Bodies may contain four of the chemical Principles, viz. Sulphur, Salt, Earth, and Mercury.

35. We took two Ounces of native Cinnabar *Cinnabar analysed.* reduced to fine Powder, and mixing it with six Ounces of Quick-lime, we put the whole into an eathern Retort, and distilling into a Bason of Water, we found a considerable Quantity of running Mercury at the Bottom thereof *. The Matter remaining behind in the Retort being boiled in a *Lixivium* of Pot-ash, and the Solution precipitated with Allum, lets fall a fine Kind of Brimstone called *Lac Sulphuris*, which will sublime into true Flowers of Brimstone, that may be melted, and run into a Roll. This Brimstone being burnt, in the common Method, under a Glass Bell, resolves into an acid Liquor, leaving an uninflamable, scurfy, terrestrial Matter behind; which being treated as an Ore, sometimes affords a small Proportion of Metal, either Iron or Copper.

36. We have here an instructive Experiment, which being fully explained might lead to considerable Discoveries. It shews that a true running Mercury may lie concealed in metallic Ores, or stony Earths; for native Cinnabar is but an Ore of Mercury, consisting, as we see, of two different Matters, Sulphur and Quicksilver, which

* We endeavoured to separate the Sulphur from the Cinnabar, by boiling some pulverized Cinnabar in a strong *Lixivium* of Pot-ash and Quick-lime, expecting the Mercury should fall to the Bottom in a running Form; but had no Success at the End of two or three Hours.

silver;

silver, which are separable by Distillation with Quick-lime or Iron Filings; and sometimes by long Boiling in a strong alkaline *Lixivium*.

*The Experiment
whether
extendible*

37. It were highly proper, if possible, to render the present Experiment general; and, if the Nature of the Thing would admit thereof, apply it to extract a running Mercury from Metals, as we have here done from a native Ore or mineral Substance. For the more intelligent Chemists agree, that the true Analysis of metalline Minerals depends upon what is called their *Mercurification*; that is, the obtaining Mercury from them. And for this Purpose there are three Methods proposed. The first is by Means of a certain Mercury, so prepared as to have a dissolving Power, and to take up the Mercuries of Metals, in the same Manner as Water dissolves Salt from Ashes. The second is by Means of certain regenerating Salts, particularly *Sal-Ammoniac*, which shall detain the more earthy Parts of Metals, and leave their Mercuries separable from them by Sublimation or otherwise. And the third Method is by Means of a large *Lens*, or double Convex Glass; in the Focus whereof, if any Metal be applied, its mercurial Part is said to separate and go off in Fume, which when collected and condensed appears to be running Mercury.

38. The first Method would be easy, if the proper Mercury for the Purpose could be readily procured. The second is extremely laborious, and requires much Patience, and Reiteration. But the third seems easy enough, and practicable to Advantage, when a Glass of three or four Foot in Diameter is at hand, the Sky serene, and the Sun shines strong *.

* See M. Homberg's Experiments, with the Duke of Orleans's Lens, in the *French Memoirs*.

39. Let us not be misapprehended as if we were here launching out beyond the Confines of genuine Chemistry, whose Office it is to keep close to the Senses, without indulging any Degree of Speculation and Hypothesis: we only mean to give an Occasion for proper Trials to be made, which alone can determine whether running Mercuries are obtainable from Metals, or whether a fixed Metal may not be obtained from running Mercury. Indeed we should be wanting to the Art we are endeavouring to improve, if we did not, at a time when almost every Chemist in *England* is preparing the *Mercurius præcipitatus per se*, request them to try whether a small Portion of their fluid Mercury is not by the Operation fixed into a solid Grain of Metal; and if so, what Metal it is, and whether more of it be not procurable by grinding their Precipitate, exposing it again to Digestion, and repeating this Operation for a Number of Times successively, till it may happen that Part of it will bear the Cupel.

40. In the same View we recommend it, to those who desire the Improvement of Chemistry, that they would procure a double Convex-Glass, three or four Feet in Diameter, and try whether, when a Metal is exposed to the Focus thereof, the metallic Matter which goes off in Fumes, being collected by a proper Vessel dextrously applied and plunged in cold Water, may not be thus condensed, and assume the running Form and other Properties of an actual Quicksilver. If these Experiments succeed, they may richly repay the Cost, by useful Knowledge at least.

41. But to proceed; we are farther to observe from the foregoing Experiment, that as common Brimstone resolves itself into an acid Liquor and an earthy Matter, we find that certain mineral

M

or

or metallic Substances will, by a proper Analysis, afford the four chemical Principles above mentioned; viz. running Mercury, Sulphur, Salt, and Earth. But it is not supposed to hold universally, that all mineral Substances should afford a running Mercury upon their Analysis; but only such of them as are properly metallic.

*Result of
the Analy-
sis of Mi-
nerals.*

42. So far as the Analysis of Minerals has been carried, it should seem that all Metals contain a running Mercury, fixed in them, as Water is fixed in dry animal or vegetable Substances *a*), and joined with a Sulphur, or an inflammable Part, and an Earth; besides a little Salt in some of them *b*). The Fossil Salts resolve into a large Quantity of Acid, which is always united with some Sulphur, and a small Proportion of Earth. Most Stones resolve into a large Proportion of Earth, and a small Quantity of aqueous and sulphureous Vapour. And Earths resolve into a mere terrestrial Substance, a little aqueous Acid, and a small Proportion of Sulphur.

43. Upon the whole therefore we may conclude, that the five Principles above laid down, viz. Water, Earth, Salt, Sulphur, and perhaps Mercury, are the true Chemical Principles of vegetable, animal and mineral Substances *c*).

AXIOMS and CANONS.

1. It appears from our preceding Enquiry, That genuine Chemistry consists in a legitimate Use of the Senses, keeping entirely to sensible

a) See *Lect. III. ad finem.*

b) See M. Homberg upon the Chemical Principles, in the *French Memoirs.*

c) No notice is here taken of Air as a Chemical Principle, for the Reason before assigned. See above, § 3. See also *Lect. III. passim.*

Things

Things, or the Law of Induction, for its Principles and Explanations *a)*; but, if it once indulges hypothetical Notions, Fiction, Illusion, and Darkness ensue, instead of sure Rules, useful Discoveries, and Light to the Understanding.

2. That the common chemical Principles are justly said to be Water, Earth, Salt, Sulphur, and Mercury; whereby many chemical Effects are explicable to common Sense and Reason, so far as to afford Rules of working, to the Advantage of the Art and of ordinary Life *b)*.

3. That as animal and vegetable Substances are resolvable into the same Principles *b)*, there is no Necessity for making more than two Distinctions or Classes of chemical Principles, *viz.* the Vegetable and Mineral; which seem to differ chiefly in this, that the metallic Species of Minerals may afford a running Mercury, whereas the vegetable and simple mineral Species will not.

4. That the different Combinations of these five chemical Principles make all that vast Variety of natural and artificial Bodies, which have hitherto been analysed by the Fire; the Difference of these Bodies appearing to arise from the different Proportions wherein these Principles are mixed. Whence, unless we except the Air, there seems no Necessity for introducing a larger Number of Principles, to account chemically for all the various Phænomena of Nature and Art.

5. That the correspondent animal and vegetable Principles may in many Cases be used for one another; so as to render volatile Salts and Oils cheaper, and lessen the Expence attending their Use in particular Arts and Trades *b)*.

a) See the whole Lecture, *passim*.

b) See *Exp.* I. II.

6. That in order to lessen the Trouble and Expence of procuring the volatile Salts of animal Subjects, these Subjects should be first purged of their Oil and unctuous Parts by boiling in Water : after which they may be made to afford volatile Salts and Spirits, as pure as unboiled Hartshorn, or purer *a*). But care must be taken not to boil the Subject too long, otherwise a Jelly will also be drawn out of it; which Jelly plentifully contains the Matter of the volatile Salt.

7. That the unrectified volatile Salts of vegetable and animal Substances are true *Sales volatiles oleosi*; that according to the Difference of the Oil abounding in them, they are properly distinguished into Salt of Hartshorn, Salt of Ox bone, Salt of human Blood, of Silk &c. But that when these Oils are totally separated from them, they become one and the same undistinguishable volatile Salt *b*).

8. That the so called *volatile Spirits* of vegetable and animal Substances, consist only of a large Proportion of Water, impregnated with some of the volatile Oil and Salt of the Subjects; and that they may accordingly be resolved by Rectification into these three Principles; so that there is no Necessity for introducing a spirituous Principle *b*).

9. That it is the Admixture of Oil which gives the Colour to volatile Salts and volatile Spirits; for when this Oil is totally separated from them, the Salt is permanently white, and the Spirit pellucid *c*).

a) See Exp. II.

b) See Exp. I, II.

c) See Exp. II.

10. That

10. That volatile Salts are obtainable from all Kinds of Land Animals, the amphibious and subterraneous Tribes, Birds, Fish, and Reptiles; from alkaline Vegetables without Putrefaction; from other Vegetables after Putrefaction; from Soot, Horns, Hoofs, and all refuse animal and vegetable Matters, such as the Pith of Horns, Urine, the Blood of Slaughter-houses, &c. and that as pure and perfect as from Hartshorn: Which affords a Rule for making volatile Alkalies and Sal-Ammoniac cheap in *England*.

11. That elementary Earth, a Substance fixed and of itself unalterable in the Fire, Air, or Water, constitutes the firm Basis, or Skeleton, of all animal and vegetable Substances; and that Water, Salt, and Oil mixed, and wedged betwixt the Particles of this Earth, constitute all animal and vegetable Substances *a*).

12. That there is only one Kind of volatile alkaline Salt, when reduced to absolute Purity; the apparent Difference betwixt the volatile Salts depending entirely upon the different Oils where-with they are mixed *b*).

13. That by endeavouring to purify the chemical Principles too high, we do but destroy their Natures *c*), or lose the Properties whereby they produce their specific Effects. Thus Oils are, by numerous repeated Distillations, lost in the form of Oils, and turned into Earths; volatile Salts fly away in repeated Sublimation; and fixed Salts turn to Earth by repeated Solution and Filtration *d*).

14. That animal Bodies naturally contain no fixed Salt, tho' the acid Vegetables, which are

a) See *Exp. I, II.*

b) See *Exp. I, II.* See also hereafter the Lecture upon *Oils.*

c) See *Exp. I, II.*

d) See Mr. *Boyle's Sceptical Chemist.*

used as Food, contain it plentifully *a)*. Whence there is lodged in the Body a Power of converting the Matter of fixed Salt into the Matter of volatile Salt.

15. That the volatile animal Salts, and the fixed vegetable Salts, differ chiefly with regard to their Volatility and Fixedness, and the Effects thereon depending, but agree in other Respects. Thus they both make an Effervescence, and turn neutral, when saturated with Acids; they are both corrosive, hot and fiery, &c. *a)*.

16. That a principal Reason of the Difficulties attending the Analysis of Bodies, is the natural Affinity, or Relation, which some of the chemical Principles have to others; whence they cohere strongly together, so as not to be well separated pure *b)*. Thus part of the volatile Oil of Animals usually rises with the same degree of Heat as the volatile Salt, and intimately mixes therewith, &c. Whence, to improve Chemistry, we should seek out for other analysing Powers besides Fire. And such an one in the present Case is Water; which imbibing the volatile Salt, more strongly than it does the Oil, thus makes a more perfect Separation; whereas Fire chiefly acts as an Analyser, when there is a considerable Difference between the Volatility of Bodies; as in a Mixture of Water, Alcohol, and volatile Salt, all which rise separately after one another; the volatile Salt first, the Alcohol next, and the Water last.

17. That the 'Mercuries of Metals may be real things, and procurable different Ways; and that possibly these Mercuries, or the common running Mercury, may be convertible into Me-

a) See Exp. I, II.

b) See Exp. I, II, III;

tal. But this Matter requires a farther Examination, and should be brought under the direct Evidence of Sense *a*).

18. Lastly, that there are certain Instruments and chemical Operations, which though little attended to may afford great Light to the Understanding, and prove highly advantageous in chemical Philosophy and Arts: we instance, for the present, the Mercurification of Metals, the powerful Furnace of the Sun, the artificial Use of the common Elements, &c. *a*) all which we recommend to the farther consideration of chemical Philosophers.

a) See *Exp.* III.



LECTURE IX.

CONTAINING

Synthetical Chemistry; or, the Art of Recomposing Bodies.

The Subject.

1. **I**N our last Lecture we endeavoured to explain what the more intelligent Chemists understand by *analytical Chemistry*, or the Resolution of Bodies; in the present we propose to give some Instances of Recomposition, or the compounding of Bodies from their separated Parts or Principles, so as to compose the Original whole again. This indeed is extremely difficult to effect universally; yet it may be done in some cases so accurately, that the recomposed Body shall be perfectly undistinguishable, by the Senses, from that which had never been separated by the Fire. And if the Art of Chemistry were perfect it would be able thus to recompose, at least in some tolerable manner, all the Bodies it divides. At present it is far from this Perfection, especially in the vegetable and animal Kingdoms; where, by reason of the vascular Texture of the Parts, such a Recomposition seems almost impracticable, unless the natural or organical Structure be some way or other preserved, or artificially imitated. We are therefore carefully to distinguish betwixt the Regeneration of organized, and the Regeneration of unorganized Bodies. As the latter is much the more simple and easy, we shall begin with that, and ascend by degrees to the more complex Kinds; so as to shew

shew where this Regeneration may be rationally expected, and where it is less to be hoped for; together with the ways of carrying this Part of Chemistry to greater Perfection.

2. This *Synthetical Chemistry*, taken in the *Synthetical* strict Sense, for the Recomposition of Bodies *Chemistry*. from their own Principles, is rather of philosophical than ordinary Use. And it will doubtless be asked, to what Purpose do we studiously endeavour to recover those Bodies by Art, which Nature affords us in plenty? We answer, it would shew an extreme Perfection and Power in Chemistry to be able to do this, and prove, either that Bodies might be taken to pieces by the Fire, without altering or injuring their natural Parts, or at least that any accidental Alteration brought upon them by the Analysis, might easily be rectified or abolished by a Recomposition.

3. But here we are to guard against a Fallacy: for supposing the Art of Chemistry so far advanced as to reinstate Bodies after their Analysis, we must not thence conclude that Nature originally uses the same Means to compose them. The Ways she uses for this Purpose would still be a new Enquiry, and ought to be diligently prosecuted, for the farther Improvement of *Philosophical Chemistry*.

4. Our first Example of Recomposition is taken from Nitre, the second from Brandy, the third from Cinnabar, and the last from Bone.

EXPERIMENT I.

The Regeneration, or Recomposition of Nitre, from its own acid Spirit and fixed Alkali.

5. We took two Pounds of refined Salt-Petre *Nitre analysed; or reduced to a Spirit.* reduced to Powder, and putting it into a Glass-
Retort a Spirit.

Retort pouted upon it a third of its own Weight of rectified Oil of Vitriol; then placing the Retort in a Sand-heat, and luting on a large Receiver, we distilled with degrees of Fire, up to the highest that Sand would give. Then suffering all to cool, we thus obtained a pure and strong *Spirit of Nitre*; which came over in red Fumes, and cannot, by any Experiment, be found to participate of the Oil of Vitriol used in its Preparation.

And a fixed Salt.

6. On the other hand, we took a Pound of purified Nitre reduced to Powder, and melting it in an earthen Crucible, cast little pieces of Charcoal into it successively, till the Deflagration ceased, and the Salt at the Bottom of the Crucible appeared sluggish, or would no longer keep fluid, with that Degree of Heat which melted it before. Then increasing the Fire, so as to make the Salt run again, we poured it out upon a clean metalline Plate, where it congeal'd into a Substance called *fixed Nitre*.

7. And thus, at two different Operations, we resolved the same Subject, Nitre, into two very different Parts; which being put together again, after a proper Manner, constitute the original Salt again, in all its Forms.

Recommended.

8. For if the alkaline Solution of fixed Nitre in Water, be exactly saturated with the acid Spirit of Nitre, till no more Effervescence appears, and yet the Mixture be not made alkaline; this compound Liquor will, by standing, shoot into true and perfect Crystals of Nitre, as we found upon Trial. And the Experiment succeeds no less, if any other fixed alkaline Salt, as that of Tartar, Pot-ash, &c. be used instead of fixed Nitre.

9. And in the same manner may common Salt be regenerated from any fixed alkaline Salt, and

and the acid Spirit of Sea-Salt; or Alum; from any fixed alkaline Salt and Spirit of Alum; so as to afford us Instances of the justest Recomposition perhaps hitherto known in Chemistry.

10. It is remarkable in this Experiment, that *Uss.* the two Substances which compose the Nitre are extremely different; the one being highly odorous and volatile; the other inodorous and fixed; the one a violent Acid; the other a violent Alkali; but upon mixing, they unite into a neutral Salt; of the very same Nature and Properties with that which afforded them.

11. From this Experiment some have ventured to affirm that Nitre is naturally generated in the same manner; but this should not be allowed till it is shewn that such an Acid and such an Alkali are to be found distinct in the places where Nitre grows. And we cannot too well remember, that there may be several physical Ways of effecting the same Thing; all which Ways are not to be presumed, but sought.

12. To this Class of artificial Recompositions may be added the Reproduction of Sulphurs and Vitriols; tho' the Experiments do not commonly succeed in Perfection. Indeed, as we above observed that the Thing itself is chiefly of philosophical Use, for that Reason very few have endeavoured to prosecute it.

13. In our present Experiment we may observe that the Nitre; tho' in both Cases it suffers a great Violence of Fire, is neither scorched nor rendered empyreumatical; which in other Cases, where the Subject is more oily, seems a principal Cause of the Difficulties found in the regeneration of Bodies; particularly such as Sugar, Turpentine, Amber, &c. Whence we are directed to analyse these unctuous Bodies, with such a degree of Heat as shall not scorch their Oil; if we desire
fire

fire to recompose them; or else to find out some more proper Analyser for them than the Fire; such as particular Solvents, capable of separating, and others of reuniting their component Parts, without having this destructive Effect.

14. The Solvents here intimated might have considerable Uses, if a competent Set of them were discovered, as directly tending to the Improvement both of *analytical* and *synthetical Chemistry*. Thus Water in some Cases is a better Analyser than Fire, as we see particularly in the separating of Salts from Earths; and thus some Chemists are said to have a Method of recovering analysed Amber, or Amber distilled for its Salt and Oil; and that by means, not of the Fire, but of an artificial compound Salt; the Instances of which Kind should be collected.

EXPERIMENT II.

Brandy resolved into its component Parts, and recomposed.

Brandy analysed.

15. (1.) To a Pint of Brandy we added half a Pound of dry Salt of Tartar, then set the containing Glass in a gentle Heat of Sand; where we observed the Salt to dissolve into a Liquor, by attracting to itself the Water of the Brandy, leaving a Spirit of Wine floating on the top. This Spirit we decanted upon a little more dry Salt of Tartar, and found that this second Salt scarce relented. Then pouring the Spirit into a Glass Receiver, we distilled it gently over, and thus obtained a highly rectified Spirit of Wine. (2.) In the same manner we distilled the saline Solution left behind upon decanting the Spirit, and thus obtained the Water of the Brandy in considerable Purity, leaving the Salt of Tartar behind,
in

in a dry Form. (3.) In the last Place, we mix-
ed the Spirit and the Water together, and di-
rectly found the Brandy recomposed, without
any considerable Alteration. *And re-
composed.*

16. The Separation and Recomposition is how-
ever less exact in the present, than in the pre-
ceding Case; because some small Part of the Salt
will always come over in Distillation, both with
the Spirit and with the Water: but when the Ex-
periment is performed in Perfection, it may pass
for a tolerably exact Recomposition.

17. To this Class may be added the Recom-
position of Wine, after its Spirit or Brandy has
been distilled from it, and the Recomposition of
Vinegar from its Spirit and *Residuum*. Though
both require a new Fret, or slight Fermentation.
Yet if the Operation be dextrously performed,
the Recomposition appears to be just and perfect.
To render the Operation perfect in either Case,
we recommend the Use of a proper intermediate
Substance, either fermentable, or actually in a
fermenting State; such as a little new Wine,
Sugar, Juice of the Grape, or the like: for
these Substances coming to work in the Liquor,
lay hold both of their aqueous, spirituous, and
saline Parts; so as to bring them into the State
of Mixture or Arrangement, on which their Per-
fection, as Wines and Vinegars, depends. And
how far this Method of Recomposition may be
extended seems hitherto little considered. *The Expe-
riment ex-
tended.*

18. In our present Experiment for the Recom-
position of Brandy, there are only two consti-
tuent Parts concerned, *viz.* Alcohol and Phlegm;
which renders the Separation and Combination
so much the easier and the more exact: nor is
there any Occasion here for an intermediate Sub-
stance, to procure, or recover, the natural Union;
because Alcohol readily mixes with Water, barely
by

by shaking, and that as intimately as is necessary to the Constitution of Brandy.

19. In Imitation of this Experiment, it is proper to enquire what other Bodies may be perfectly separated into different Parts by the Way of Menstruum, Absorbent, or Precipitant; so as to leave the separated Matters unaltered in their Natures, and fit to compose the original Substance again. This Enquiry depends upon finding out the secret Relations which exist between particular Bodies; and these Relations can only be discovered by particular Trials a).

Farther
Uses.

20. This Experiment shows an useful Method of obtaining Spirit of Wine from Brandy, without Distillation, which may be practised to advantage in the large Way of Business; viz. by adding Pot-ash to the Brandy once distilled, and brought to the Size commonly called *three Fifts*, that is, three Parts Alcohol and two of Water: For the Pot-ash so employed is easily recoverable without much loss, barely by boiling the Lixivium in an Iron Pot; by which Means being dried it will serve for the same Purpose again. This slight Experiment has proved of eminent Service, where large Parcels of Brandies have been to be rectified in a small Compass of Time.

EXPERIMENT III.

Cinnabar recomposed, by the Union of its two component Parts, Sulphur and Mercury.

Cinnabar
recomposed.

21. Having found, in our last Lecture, that native Cinnabar is composed of Sulphur and Mercury b), we took four Ounces of common Brim-

a) See M. Geoffroy's Paper to this Purpose in the French Memoirs.

b) See Lett. VIII. Exp. III.

stone,

stone, and melting it in a earthen Pan, over a dull Fire, added by Degrees twelve Ounces of crude Quicksilver, first made warm, and stirred them well together, till no Globules of the Quick-silver appeared; then suffering the Mass to cool, we reduced it to Powder, and sublimed it, with a proper Degree of Heat; and thus obtained an artificial Cinnabar, which being ground fine, and compared with the natural, appeared undistinguishable from it.

22. The regenerated or artificial Cinnabar has *Uses*. not the stony Form of the native; this Form being accidental in the Mine, and determined by the Circumstances of the Place, as the Form of the regenerated Cinnabar is by the Figure and Make of the Vessel wherein it was sublimed. But if the two be compared together, in all other Respects there appears no Difference, when the Operation is justly performed.

23. This Experiment shews us the common Method of preparing artificial Cinnabar, which may, in the large Way of Business, be thus sublimed in a tall earthen, or coated Body, with its Head well luted on, and so placed in a Sand-Heat as to touch the Bottom of the Iron-Pot, whilst the Sand rises above the Matter contained in the Vessel. And here it is a principal Caution to use a brisk Fire, that the Operation may be finished in three or four Hours Time. And probably, if only one Part of Sulphur be used to about four Parts of Quicksilver, the Cinnabar will be the finer; for about thirteen Ounces of running Mercury may be recovered from a Pound of native Cinnabar.

24. And thus we have an Instance of a perfect Recomposition, in a metallic Body, or Subject of the mineral Kingdom: for the Experiment succeeds alike, when the Sulphur and Mercury
of

of native Cinnabar is used *a*). To this Class might be referred the Reduction, or Recovery, of all the Calces of Metals to a metallic Form again, by the Addition of any inflammable Matter, which they lose in their Calcination; as also the Regeneration of Antimony, by melting its Regulus with Sulphur; the Regeneration of Ores, by melting their Metals with Sulphur, stony Earths, &c. so as to mix them again; and all other Instances of this Kind.

25. The present Experiment is of considerable use, particularly in natural Philosophy, and Metallurgy; as it shews us that a very large Proportion of fluid Mercury may, by Means of a very small one of Sulphur, be fixed into a Body of a stony Hardness, such as the native Cinnabar. Whence we should not be over-hasty to conclude that Mercury cannot assume a metalline Form *a*). Some metallurgical Chemists contend, that Mercury is nothing else but a Metal, overdosed with that Part which gives ductility and softness, which remarkably belong to all the Metals when amalgamated with Mercury. In short, whoever duly lays together all the Properties of Mercury, may perhaps find Cause to allow it a metallic Nature *b*).

EXPERIMENT IV.

An Attempt to recompose Bone from its Ashes.

*Bone re-
composed.*

26. (1.) We took a large Ox-Bone, and made a strong Jelly thereof with Water in the Digestor *c*); then (2.) in an open Fire we burnt and calcined the Bone to whiteness, without destroying

a) See *Let. VIII. Exp. III.*

b) See the Place last quoted.

c) See *Let. VI. Exp. VII.*

its external Figure; so that in other respects the Bone was reduced to mere Ashes, or separated from the Principles of Water, Oil, and Salt, which it originally contained. In this state we found it extremely brittle and crumbly; but (3.) putting it into the Digestor again with the Gelly, and warming them together over the Fire for some time, then taking the Bone out, and suffering it to dry in the open Air, we found that it gradually hardened, and recovered, in some tolerable Degree, the Appearance, or Colour and Consistence, of the natural Bone.

27. Gelly, by an Analysis, is found to yield the same Principles as Bone itself *a*); or to contain the matter, not only of Water, but of Salt and Oil, and a little Earth: so that to use this Gelly, is the same thing as to use the Water, Salt and Oil; all which being thus together soaked into the Skeleton of the Bone, restores it in some Degree to its natural State.

28. But to use the direct volatile Salt and Oil of the Bone for this Purpose, were to use two things which did not exist in those Forms in the Bone; for to separate the volatile Salt and Oil from Bone, requires a much greater Degree of Heat than that natural to an animal Body; so that they are never thus separated in the Body, whilst that remains in its natural State. Yet a Degree of Hardness (with Discoloration, on account of the black and scorched Oil of the Subject) may be given to Bone-Ashes by the separated Oil, or even by Water, as we see in Tests.

29. We were farther encouraged to use the Gelly of the Bone in this Experiment, from observing by repeated Operations in the Digestor *b*), that all the active Principles of the Bone might

a) See *Let. VIII. Exp. II.*

b) See *Let. VI Exp. VII.*

be got out and united with the Water added to extract them; so as to leave nothing but a little Earth behind, resembling the Ashes left upon a dry Calcination in a violent Fire. Whence we are plainly instructed in the Nature of animal Gelly, with its Uses to the Body. And hence also we learn the Nature of Mucilages, Size, Glues, and may understand many things relating to Medicine, the animal Oeconomy and Arts.

Uses.

30. This Experiment might be rendered more successful, if we could procure the tenacious Glue or Cement, which obstinately remains in the Pores of the Bone, even tho' long detained in the Fire. This Glue seems to be an intermediate Substance, of a middle nature betwixt Gelly and elementary Earth; whence it were proper to try whether, by grinding the elementary Earth fine and digesting it with Gelly, some such tenacious Glue could not be procured. This also might open the way to a History of Glues, which is extremely wanted in Chemistry, natural Philosophy, and Arts.

31. If a promiscuous Mass of elementary Earth be used, instead of that which retains its natural vascular Form, a Kind of *Callus* will be thus produced, instead of a regular Bone. Whence we may be enabled to judge of the Nature of the *Callus* formed in the Bones of Animals.

32. After the manner of our present Experiment, we might also attempt to recompose vegetable Subjects. But before any thing of this Kind is done to Perfection, Chemistry will require the Assistance of mechanical Contrivance, and many Improvements from the Anatomy of Plants; particularly it must learn to preserve the native Spirits of Vegetables, upon the Analysis, or else the artificial ways of imitating and introducing such Spirits into the Subject. These Spi-
rits

rits are extremely apt to fly off with Heat, yet may in good Measure be collected and preserved by Art. And unless they are thus preserved, the Subjects will want their native Tastes and Odours, which depend upon these Spirits, or subtile, volatile Matters.

33. The highest Degree of Recomposition is, *Perfect*
when a Body is perfectly resolved into its Prin- *Recompo-*
ciples, (suppose a Vegetable Subject into Water, *sition.*
Salt, Oil, and Earth) and these are again put together, so as to form a Subject undistinguishable from the Original. In order to attain this Perfection, let the thing be first tried in similar, unorganized Bodies; as Glass, Turpentine, Amber, Vegetable Juices, Wines, Sulphurs, Ores, &c. proceeding by slow Degrees, up to the more dissimilar and organical Bodies; such as vegetable and animal Subjects.

34. We have seen that, in many Cases, a true Resolution and Recomposition are practicable; and as Chemistry improves, the Business of *Analysis* and *Synthesis* must likewise improve.

35. But let it be observed, that the Power of *The Im-*
Chemistry is not limited to the Business of just *perfect*
Resolutions and Recompositions: it can produce *useful.*
numberless Effects without going to this Exactness. Thus it already analyses and recomposes, or separates and mixes, all the natural and artificial Bodies, in its own imperfect manner. And thus it has furnished us with all Chemical Medicines; as Tinctures, Extracts, Spirits, Oils, Waters, Essences, &c. and the several Commodities of Sugar, Wine, Alum, Salt, Pot-Ash, Aqua-Fortis, Oil of Vitriol, Soap, Glass, &c. &c. &c. For without attempting a perfect Separation or Recomposition of the chemical Principles, a gross Separation or Mixture of two or three of them will frequently afford very use-

ful Substances ; so that Chemistry, tho' it remains imperfect, is still highly serviceable.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, that we cannot safely conclude Bodies to have been originally composed of the same Principles, into which the Fire resolves them *a*).

2. That as the Fire, in many Cases, proves a just Analyser, and resolves Bodies into their constituent Parts, without Alteration ; so, in others, it quite perverts and changes their Nature and Properties ; especially by scorching the Oil of a Subject which abounds therewith *b*).

3. That the perfect Regeneration of Bodies can take place in such Cases only where the Fire, or other Instrument, is a true Analyser, without adding any extraneous thing of its own, or any way altering or subverting the Nature of the Parts separated *c*).

4. That the Business of Recomposition is to be distinguished into three Kinds, *viz.* mineral, vegetable, and animal, differing in Degree of Facility ; the mineral Kind being the easiest, and therefore to be first cultivated, in order to improve *Synthetical* Chemistry, and render it more advantageously practicable in organical Bodies *d*).

5. That *Synthetical Chemistry* is more imperfect than the *Analytical* ; or that the present Chemistry divides natural Bodies more perfectly than it puts them together again, for want of more proper Analysers than Fire, and more

a) See §. 3. & Exp. I.

b) See Exp. I. See also *Let. VIII. Exp. II.*

c) See Exp. I, II, III, IV.

d) See Exp. I, III, IV.

suitable Methods and Menstruums than are hitherto discovered *a*).

6. That a new Composition is usually made in every chemical Resolution. Thus when Nitre is separated into an acid Spirit, its fixed Salt remains compounded with the Oil of Vitriol *b*). When Mercury is separated from the Sulphur in Cinnabar, the Sulphur remains united with the Quick-Lime, or Iron-Filings *c*). When Water is separated from Brandy, the Water unites with the fixed Salt, and leaves the Spirit to float separate *d*). And this appears to be generally the Case; so that the Separation is made by some intermediate Body, which unites with one Part, and not with the other of the Subject *e*). Whence we are directed to find out the *Mediums of Mixture and Recomposition*, as well as of *Separation*, in order to perfect *Analytical and Synthetical Chemistry*.

7. That Bodies endowed with a native Spirit are hard to recompose, unless this Spirit be some way artificially preserved *f*). Thus for Instance, Seeds, Roots, Flowers, &c. may be dried in close Glasses, with blind Heads, set upon a gentle Sand-Heat; then taking the Subject out, and separating its Principles, the Oils and Salts being afterwards impregnated with the native Spirit of the Subject, remaining in the Blind-Heads, may thus serve to recompose the whole in some tolerable Degree.

8. That animal Gelly is a Mixture of all the Principles of an animal Subject, *viz.* much Water,

a) See the preceding Lecture, *passim*.

b) See *Exp. I.*

c) See *Lect. VIII. Exp. III.*

d) See *Exp. II.*

e) See *Exp. I, II, III, IV.*

f) See §. 31. &c.

a moderate Proportion of Oil and Salt, and a little Earth *a*). Whence we learn the physical Cause why Gelly is nutrimental; why animal Substances so much abound therewith; its Uses in the Body; its restorative Nature, &c. And hence we have a Foundation for the natural and experimental History of Gellies, Size, Glues, &c. *b*).

9. That the Business of Analytical Chemistry is deficient, which ought to afford the Rule of operating to Synthetical Chemistry *c*). Thus most of the Analytical Operations hitherto performed, are but superficial Attempts to enter and open the Substances of natural Bodies; for which purpose, in some Cases, long Digestions, repeated Reverberations, vaporous Mixture, exquisite Triture, continued Fusion, subtile Precipitation, &c. are required. Whence the Improvement of Synthetical Chemistry will greatly depend upon the Improvement of the Analytical.

10. That another way of improving *Synthetical Chemistry* is carefully to observe what Steps Nature takes in supplying and recruiting the Bodies of vegetable, animal, and mineral Substances; and whether there be any mineral Instances of Regeneration in Nature, from the direct Principles themselves without Addition; or whether this Action be not usually performed by some certain Assistance within the Power of Art to procure; and particularly what is the Office of the Air, Water, and Fire, in bringing about this natural Operation *d*) in the way of *Fermentation, Putrefaction, Accretion, Nutrition*, and the general Principles of Motion or Life *e*); and whether

a) See *Exp. IV.* See also *Lect. VI. Exp. VII.*

b) See above § 28. See also *Lect. VI. Exp. VII.*

c) See *Lect. VIII.* and the present *passim*.

d) See *Exp. I.*

e) See *Lect. VII. passim*.

the common Elements do not contribute some Part of their Substance, as well as Energy, in the Change *. From such an Enquiry, conducted in a regular Manner, it should seem that some capital *Canons* might be derived for improving this grand Part of operative Philosophy.

* See the preceding Lectures upon the Elements.



LECTURE X.

CONTAINING

The Curation of Vegetables; or the Means of preparing and fitting vegetable Subjects for various Uses, viz. Brewing, Distilling, Vinegar-Making, &c.

The Subject.

1. **W**E are now proceeding to examine into the Nature of Seminal Vegetation, and the Curation or Preservation of Vegetables, with a View to the Improvement of Chemistry and the Arts thereon depending.

Its Extent.

2. The Subject is of large Extent, and if duly prosecuted, might tend to the Enrichment of the present Arts, or the Discovery of new ones. For on regulating the Growth, and on the Curation of Vegetable Productions, depends the Perfection of Corn, Wines, Malt, Bread, Sugar, Tobacco, Spice, Drugs, Simples, Dying-Stuffs, and the like. And new Discoveries either in Vegetation, or Curation, might easily introduce new Trades; as has been the Case in Sugar, Tobacco, Wines, Spirits, &c.

The Procedure.

3. By Experiments in Vegetation, we here propose to shew the Methods of regulating or conducting this natural Power for the Service of Arts; by directing it to answer particular Ends. Thus by stopping short towards the Beginning of Vegetation in Barley, we procure Malt; and by permitting the Grapes to hang till they grow not only ripe, but almost dry, upon the Vine, we procure rich sweet Wines. And thus we may

may stop Vegetation at any Period, or continue it longer than ordinary, according as the Occasions of different Arts require.

4. By Experiments in *Curation* we would shew *Curation* the Methods of collecting, preparing, and se-^{what.} curing vegetable Commodities; so as that they may long remain sound, perfect, and fit for Service. And thus our present Lecture will consist of two Parts; the one relating to the ways of *growing* Vegetables, according to the Uses for which they are intended, and the other to the *gathering* and *preserving* them, so as to have them constantly ready at hand, when they come to be required in Use.

5. Our first Experiment therefore is calculated *The De-* to shew the Method of stopping the natural Pro-^{sign of the} cess of Vegetation in the Seed; so as to prepare *Experi-* Grain, Pulse, Nuts, Mast, and Roots, for the *ments.* making of Beer, Vinegar, and Spirits. Our second is designed to shew the Method of curing both fermented and unfermented vegetable Juices, so as to make them keep sound and good for several Years. Our third Experiment tends to shew the Method of curing vegetable Juices by Decoction, or Inspissation, for the Service of Brewing and Distilling. And our fourth and last Experiment will shew the Method of curing Yeast, the Flowers of Wine, and Wine-Lees, for the Service of several Arts. These Experiments now follow in order.

EXPERIMENT I.

The Method of stopping the Natural Process of Vegetation, with a view to Malting; or the Preparation of Grain, Seeds, Pulse, Nuts, Mast, and Roots, for the making of Beers, Vinegars, and Spirits.

6. We

Malting.

6. We plucked up a Parcel of Garden-Beans, after they had been suffered to lie in the Ground about six Weeks in the Winter-Season; and found each Bean beginning to split, or separate, into its two *Lobes*, whilst the *Radicle* was shot out some Inches downwards, and had begun to take Root in the Ground; the *Plume* also, which becomes the Stalk of the Bean, being risen to the height of two Inches. In this state we dried a few of these over a clear Fire, and thus found them turned to a Kind of Bean-Malt, that tasted sweetish, bit mealy betwixt the Teeth, and dissolved freely in warm Water; so as to afford a Wort, fit for fermentig with Yeast into a Kind of Beer or Ale.

7. This Experiment instructs us in the ordinary Process of Malting; which, in the Case of Barley, is conformable hereto, and in the Case of Malting *Indian Corn* is the Process itself *.

The Process of Malting.

8. In making Malt from Barley, the usual Method is to steep the Grain in a sufficient Quantity of Water, for two or three Days, till it swells, becomes plump, somewhat tender, and tinges the Water of a bright brown, or reddish Colour. Then this Water being drained away, the Barley is removed from the steeping Cistern to a Floor, where it is thrown into what they call the *Wet-Couch*; that is, an even Heap, rising to the Height of about two Foot. In this *Wet-Couch* the capital Part of the Operation is performed; for here the Barley spontaneously heats, and begins to grow, exactly in the same manner as in our present Example of Beans; shooting out first the *Radicle*, and then if suffered to continue, the *Plume*, *Spire*, or *Blade*. But the Process is to be stopped short at the Eruption of the *Radicle*,

* See below §. 10. See also some Experiments to this Purpose in the *Philosophical Transactions*.

otherwise

otherwise the Malt would be spoiled. The way to stop it is, to spread this Wet-Couch thin over a large Floor, and keep it turning once in four or five hours, for the space of two Days, laying it somewhat thicker each time. After this, the Malt is again thrown in a large Heap, and there suffered to grow sensibly hot to the Hand, as it usually will in twenty or thirty Hours time; then being spread abroad again and cooled, it is thrown upon the Kiln, to be dried crisp without scorching.

9. And this is the general Process of Malting, wherein almost every Maltster has his secret or particular way of working. But to render the Operation perfect, the following Cautions must be observed: (1.) That the Barley be newly thrashed, or at least newly winnowed; (2.) That it be not mixed or made up of different Sorts; (3.) That it be not over steeped in the Cistern, or ly there so long as to make it soft; (4.) That it be well drained; (5.) That it be carefully looked after in the Wet-Couch, so as to stop the first Tendency of the Blade to shooting; (6.) To turn the Wet-Couch inside outermost if the Barley comes (that is, shoots) more in the middle than on the sides; (7.) To keep it duly turning after it is out of the Wet-Couch; (8.) To give it the proper heating in the dry Heap; (9.) To dry and crisp it thoroughly upon the Kiln, but without a fierce Fire, so as to be several Days in drying a Kiln of Pale Malt. If these Directions be carefully observed, the Malt will always be good.

10. The Method of Malting *Indian-Corn*, or *Virginia Wheat*, is much less laborious. For if this Corn be buried two or three Inches deep in the Earth, and covered with the loose Mould dug up to make room for it, in ten or twelve Days time the Corn will sprout, and appear like a green

a green Field ; at which time being taken up, and washed or fanned from its Dirt, it is immediately committed to the Kiln, and by this means it becomes good Malt, exactly as Beans so treated would do.

11. It is observable of this Corn, that both its Root and Blade must shoot to a considerable length, before it will make Malt. And perhaps this is the Case in all large-bodied Grain and Nuts *a*).

Extended. 12. It might be of Service to transfer this easy Experiment to the making of Malt from Barley, Rice, and the other small Grains and Seeds : but the Attempt may be attended with Difficulties ; because in the making of Malt, the Barley must be suffered to grow in its Root only, and not in the Blade ; whence it would be difficult, at first, to hit the exact time for taking it out of the Ground. And, again, as the Grain is so small, it might prove troublesome to separate it from the Earth or Mould. However, the thing may deserve to be tried *b*).

Its Effects, and End. 13. It is a Consideration of a higher Nature to determine the physical Effect procured by Malting, and whether the End may not be obtained by cheaper and less laborious Means. The physical Difference betwixt malted and unmalted Corn appears to be the Production, or Extrication, of a sweet saccharine Substance in the Malt, which is wanting under that form in the Corn. And it is the sweet Substance alone, which we require

a) It may be worth trying, whether the same Process is not, with due Care, applicable to the Malting of Turnips, Potatoes, Carrots, Parsnips, &c.

b) And possibly some Contrivance might be found, by the means of large Hair-Cloths, or otherwise, to inclose the Grain, so that the loose Earth should not mix among it ; and at the same time an Opportunity be afforded, of commodiously examining how far the Barley is come at any time after lying

in

in Malt for the making of Beer, Ale, Vinegar, and inflammable Spirits *a*). But even unmalted Corn, duly treated, may be made to afford Beer, Ale, Vinegar, and Spirits: This, therefore, may intimate to us a way of making such Liquors, without the formal Extrication of any remarkably sweet saccharine Substance. According to some Trials we have made, unmalted Corn affords half the Quantity of inflammable Spirit by Fermentation and Distillation, as the same Corn would do when malted. And suppose that unmalted Corn were to be made into a Kind of Dough, or Paste fermented with Yeast, as is usual for Bread, and then baked; would not this be a cheap Substitute for Malting *b*)? At least, it deserves to be tried, how much Beer, Ale, Vinegar, and Spirit, might be procured this way, compared with that other of Malting.

14. On the other hand, if only a sweet saccharine Substance be required in Malt, are there not cheaper and easier ways of procuring it than by Malting? Do not many Trees afford such a saccharine Juice, by Tapping in the Spring, without prejudicing the Trees? Is not young green Corn itself remarkably sweet; and does not this sweet Juice enter the Composition of the Ear, and there remain fixed, or almost lost in a saccharine Form, till recovered by Malting? Here is a Door opened for explaining the Nature of Sweetness, and deducing the particular History of Sugar. Such a Work, for its Usefulness in Trades and ordinary Life, we wish were extant; and till some considerable Progress is made there-

a) See *Let. VII. Exp. I, II, IV.*

b) They are said to brew after this manner in some Countries.

in, the Art of Malting, and all those that depend upon it must remain short of perfection.

15. Those, who are disposed to go upon the Enquiry, may please to compare the Art of Starch-Making with that of Malting, and particularly try whether some considerable Uses may not be made of the Refuse Liquors produced in both Arts. The high-coloured Liquor drawn from the Barley in the steeping Cistern is a vegetable Tincture, that might, if not by itself, yet by being used instead of Water to ground Malt, be worth fermenting and distilling for Spirit; and the Starch-Makers refuse Liquors have been observed to contain a Quantity of inflammable Spirit.

16. Our present Experiment may in this respect be made general, that it shews us there are different times of stopping, or preventing, the farther Growth of Vegetables, for the Service of Arts. And this Doctrine may be extended to the forming a Set of general Rules, for gathering the different Parts of Plants, at different Seasons of the Year, for different Uses.

Uses.

17. Thus Roots, for instance, to be had perfect, should be gathered and dried in the Spring, before the Leaves are formed; Leaves should be gathered when they are fully opened, but before the Flowers appear; Flowers when they are not fully opened; and some, as red Roses, in the Bud. Seeds are to be gathered when full ripe, and beginning to dry, before they fall spontaneously; and Trees are generally best felled and flaved for their Bark in the Beginning of the Spring. But all this is to be understood of the common Uses of the Subjects; for there are many particular Occasions, which require them immature. Thus Buckthorn-Berries, should be ripe gathered for making

making the Syrup, but unripe, for making the Painter's Colour called *Sap-Green*.

EXPERIMENT II.

A Method of Curing both unfermented and fermented vegetable Juices.

18. (1.) We melted Brimstone in an Iron *Matching* Ladle, and dipping slips of coarse linnen Cloth *or Fumi-* therein, made what the Wine-Coopers commonly *gating* call Match. (2.) We took a slip of this *with* Match, and setting one end thereof on fire, *Brimstone.* put it into the Bung-Hole of a Cask, which being at first loosely stopped, suffered the Match to burn nearly out. Then the Bung being driven in tight, we set the Cask aside for an hour or two, and found that this Operation communicated a violently pungent and suffocating Scent to the Cask, with a considerable Degree of Acidity, which is the Gas and acid Spirit of the Sulphur. We now filled the Cask with a very small Wine, which had scarce finished its Fermentation; and bunging it down tight, we put it in a proper place to clarify.

19. This is the common Method of matching Cask for Wines, but particularly for Stums. It is an useful Experiment; for poor Wines could scarce be kept potable a few Months without it; nor could Stums be prepared in large quantities by any other Method commonly known.

20. By Stum we understand the unfermented *Stum* Juice of the Grape, several times racked and *what.* drawn from its Sediment, the Cask being every time thus fumigated with Brimstone, to prevent the Liquor from fermenting, as it would otherwise readily do and so become Wine. It is the Fume of the burning Sulphur which thus stops all Tendency to Fermentation, and continues the natural Juice of the Grape in a sweet state, fit to be readily

dily mixed with Wines instead of Sugar; for which purpose it is very much used in *Holland*, and other Countries, as also for giving a new *Fret*, or Briskness, to decayed Wines; so that very large Quantities of this Stum are annually imported to all Parts along with the Foreign Wines. And after the same manner a Stum is prepared in *England* from the Juice of Apples, which serves the ordinary purposes of the Wine-Cooper.

*Inconveni-
ences of
Matching.*

21. The principal Inconveniences in this Method of matching the Cask are these; (1.) that it communicates a nauseous sulphureous Taste and Smell to the Wine; and (2.) that it is not applicable to red Stums, or red Wines, without greatly impairing, or almost destroying their Colour; whence the Stums in common Use are always white, the Produce of white Grapes. And because this Method of Matching does not suit with red Wines, hence it is, that all red Wines are usually dosed with Brandy in order to preserve them. And for Wines in general, it might very well suffice to burn a little Spirit of Wine in the Cask; and if they want Strength, or Spirit, to preserve them sound, to add Brandy or Spirit of Wine, proportionably. By which means they may be preserved without any nauseous Smell, or Taste, which always attend the Way of matching; tho' matched Wines lose of their sulphureous Taste, and Odour by long keeping. But for Stums, there is no other Way commonly known and practised, to preserve them, but by using the Fumes of Sulphur.

*The Ex-
periment
extended.*

22. The Experiment however is almost general, and may be applied to advantage in the case of all fermented Liquors, and again to unfermented vegetable Juices; such as those of Citrons, Quinces, Oranges, &c. which it prevents from running

ning into Fermentation or Putrefaction. And this Effect it seems to have, chiefly by stiffening the Air, or weakening its natural Elasticity *. For as all vinous Fermentation is found to generate Air, so the burning of Sulphur is found to stiffen or destroy Air. And hence it seems to be, that the Fume of burning Brimstone readily checks the Fermentation of Liquors; so that if a Cask, by fretting or fermenting, appears ready to burst its Hoops, a Dish of burning Brimstone held under it will soon quell the Motion: which is one known Method of checking or suppressing vinous Fermentation.

EXPERIMENT III.

The Method of curing vegetable Juices by Decoction, or Inspissation.

25. We made an Infusion of Malt, in the common Manner of Wort for Beer or Ale; then letting it stand to clarify, we decanted the clear Liquor, and boiled it over a soft Fire to the Consistence of Treacle: in which State it will long keep sound, or fit for making Beer, Vinegar, or inflammable Spirit. *Wort inspissated.*

24. This Experiment shews us a general Way of reducing fermentable Subjects to a small Compass, and of securing them against external Injuries. Thus a Kind of Treacle from Malt might be procured in cheap Years, for the Service of the Vinegar-maker, the Brewer, and the Distiller. The Method is likewise applicable to any other sweet or saccharine Juice; as that of Grapes, the Tappings of Trees, the fermentable Juices of Summer Fruits, and of certain sweet Roots, as Parsnips, &c. *The Experiment extended.*

25. These inspissated Juices, if not boiled too high or scorched in the Operation, are easily

* See Mr. Hale's *Vegetable Staticks*.

brought back to a due Degree of Thinness with Water, and fermented in the same Manner, and for the same Purposes, as they might have been before they were boiled: So that Beer, Vinegar, or Spirits may be thus commodiously procured, at any Time, even in hot Climates; and it should seem that Brewers and Distillers might also reap some Advantage from a prudent Use of this Expedient.

26. The Wine-Merchant might thus order the Juice of Grapes, or Stum, to be boiled down in Wine Countries, and so left fit to be reduced by Water and fermented into Wines in others. And for this Purpose the poorer Vintages might serve, as well as the rich; excepting only that the Rob, when reduced by Water, would not afford so much Wine as the thicker or richer Juices. But the Operation must be performed with considerable Exactness, to make it succeed so as to produce artificial Wines perfectly like the natural.

27. This Process also seems applicable to Hops, which in cheap Years, may be thus made into a Kind of Extract, without any Loss of their valuable Parts; whereby the numerous Contingencies attending that Commodity, might in good Measure be prevented. But there would here be Danger of Fraud; because the Extracts of Gentian, Centaury, or other bitter, stomachic Vegetables might be mixed with the Extract of Hops, so as not to be easily discovered. Yet perhaps this Inconvenience would not be greater than that generally suffered already; for many, no doubt, are well assured by Experience, that the Extract of Gentian is a wholesome Bitter, which might very well supply the Place of Hops in Brewing.

28. A Process somewhat of this Kind is frequently practised in Wine-Countries; viz. either by

by suffering the Grapes to grow almost dry upon the Vine; or else by boiling down their Juice, till it becomes sufficiently thick to afford such rich Wines as *Canary* or *Frontignac*; whose Strength may be readily imitated by adding a less Proportion of Water to the Rob, or inspissated Juice of Grapes, in the Manner above explained *.

29. Before we quit this Process we would recommend it to be tried, upon the Juice that may be easily expressed from a vegetable Subject commonly thrown away as useless: we mean the Shells of green Pease, which by being barely boiled in Water, communicate a saccharine Sweetness thereto; so that the Liquor has been made into tolerable Drink, and a good Spirit.

EXPERIMENT IV.

A Method of curing Yeast, the Flower of Wine, and also Wine-Lees, for the Service of Distilling, Wine-Making, Vinegar-Making, &c.

30. We took a Quantity of common Ale-Yeast, *Yeast cured and put-
and putting it into a close Canvas Bag, gently and pre-
squeezed out the Moisture in a Screw-Press, till served.
the remaining Matter was left as hard as Clay;* and in this State having packed it close in a tight Cask, and secured it well from the Air, it kept fresh and sound for several Months; as has been often experienced by others.

31. This is an Experiment of considerable Use *Use.* to Brewers and Distillers, who employ very large Quantities of Yeast, and yet seem in *England* to have no good Method of preserving it, or raising Nurseries thereof; for Want of which they sustain a considerable Loss. Whereas the Brewers in *Flanders* make a great Profit, by supplying the

* §. 23—27.

Malt-Distillers of *Holland* with Yeast, which is rendered lasting and fit for Carriage, after the Manner of our present Experiment.

The Experiment extended.

32. The same Method is practicable to much greater Advantage in the Yeast of Wine, and in Wine-Lees, if they could be imported into *England*. For by this Means we might easily imitate the Wines and Brandies of foreign Growths; the Lees and Yeast of Wine readily affording an essential Oil, by Distillation, of which a small Proportion will flavour a large one of Wine or Brandy. But a shorter and more perfect Way is to let any tasteless, or other proper Wine, fret or stand, for some Time, upon such Lees, or Wine-Yeast, whereby it will to great Advantage acquire the natural Taste and Flavour of the Wine, to which the Lee, or Yeast, belonged.

Perfect Curation what.

33. Thus we have given a few Examples of *Vegetable Curation*, on which the Improvement of several Arts depends. We cannot go through all the Species of it, for that would be an immense Labour; nor are Men hitherto arrived at the perfect Method of preserving Vegetables in their natural Form, with their Colours, Odours, and other sensible Qualities, for any Number of Years. Yet something considerable might be done in this Way, by proper Application. Fruits may long be preserved fresh in Spirit of Wine, first well saturated with the Skins and tinging Parts of the Fruit. And many of them may be tolerably preserved in perfectly fermented Liquors, which generate no more Air. The more solid Kinds of Substances may be commodiously cured, by gently drying them in the Sun, Shade, or other slack Heat. Thus Pease, or Beans, being dried young in a slack Oven, in their proper Season, may be boiled green and tender, in the Winter, almost like those new gathered. Certain Ways of pre-

preserving Fruits, and other vegetable Subjects, both in a dry and moist Form, with Sugar, are now generally known : But there are some extraordinary Means of curing several particular Kinds of Bodies reserved as Secrets by Artists ; tho' even these might be exceeded, if we had a thorough Knowledge of the present Subject. The Design might also be extended to the animal Kingdom, under the Name of *Animal Curation* ; the compleat Art whereof would prove highly useful at Sea.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, that Men have Power to stop the Course of Nature in Vegetation, so as to make this Principle answer their own particular Ends and Designs ; whence Arts may receive considerable Improvements *a*).

2. That the Art of Malting is farther improvable by a general Acquaintance with the Nature of Vegetation, vegetable Juices, the Art of Fermentation, and the Art of Sugars *b*).

3. That the Labour and Expence attending the Art of Malting may, in some Measure, be saved, by procuring and separating the sweet Juices of Vegetables as Nature affords them ; or by boiling them down to a Treacle or saccharine Substance *c*).

4. That there are different Seasons of the Year peculiarly fitted to the collecting or procuring of these Juices, and all other vegetable Matters, according as they are required ripe or immature *d*).

a) See *Exp. I.*

b) See *Exp. I. II.*

c) See *Exp. I. III.*

d) See *Exp. I.*

5. That the Fumes of burning Sulphur have a great anti-fermentative, anti-corruptive, or preservative Power upon vegetable Juices *a*); and this without rendering the Liquors unwholesome, tho' the Fume is disagreeable, and of itself suffocative.

6. That the Fumes of burning Sulphur have a Power of discharging the Colour of red Wines *a*); and on a like Account these Fumes are usually employed for the Blanching of Silks, Flannels, &c.

7. That *Vegetable Curation* depends chiefly upon the Exclusion of the Air and all superfluous Moisture; and this either singly or conjointly *b*)

8. That *Vegetable Curation* consists in keeping all the Principles of a vegetable Subject together undestroyed, in their natural Texture or Arrangement *b*).

9. That all sweet vegetable Juices may be preserved sound and serviceable, by inspissating them over a soft Fire; so as to throw off their superfluous aqueous Parts, and leave the sweet or saccharine Substance behind, in a state fit for Fermentation, upon the Addition of fresh Water *c*).

10. That several bitter vegetable Juices, capable of answering the End of Hops in Brewing, may be inspissated by the Fire, and preserved for that Purpose *c*).

11. That those extremely corruptible Substances, Yeast, the Flowers of Wine, and Wine-Lees, may be preserved sound, barely by freeing them from their superfluous Moisture, and securing them from the external Air and too great Heat *d*).

a) See *Exp* II.

b) *Exp* II, III, IV.

c) See *Exp* III.

d) *Exp* IV.

12. That the Business of *Vegetable Curation* may receive great Improvements by a proper chemical Enquiry, made with a direct View to this Subject; from whence many farther Advantages are derivable to Arts and Trades, particularly to the Sugar-Colonies abroad, to Brewers, Wine-Makers, and Distillers in hot Countries; and that the Enquiry likewise might be advantageously extended to *Animal Curation* *.

* See *Exp. IV.*



LECTURE XI.

CONTAINING

Ways of illustrating and improving the Arts depending upon Vegetable FERMENTATION; particularly Brewing, Distilling, Vinegar-Making, &c.

The Subject.

1. **I**N our last Lecture we endeavoured to shew the Method of procuring certain vegetable Commodities, and preserving them uncorrupted, for the Service of Arts: In our present, we shall consider some Uses of these Commodities, when thus preserved; or the Ways of employing them, so as to afford various Preparations for the commodious carrying on of Trade, and the Business of ordinary Life.

2. As our Consideration is restrained to the vegetable Kingdom, the Arts that will chiefly come before us at present are, those of Wines, Sweets, Malt-Liquors, Vinegars, and Brandies; in all which we have already made some Progress *. But there remains much behind for the Improvement of these Arts; which lie in a State far from that Simplicity, on which their Perfection seems to depend.

The Design of the Experiments.

3. These Arts we shall here endeavour to improve by four direct Experiments. The *first* is capital, and calculated to shew the Method of reducing vegetable Juices, cured by Decoc-

* See *Lect. X.*

tion or Inspissation *, back to a State fit for affording Vinegars, Wines, and Brandies by Fermentation; and at the same Time to exhibit a new Method of making an artificial *Must*, or *Stum*, as good as the natural, and equally fit for refermenting, fretting, improving, and making Wines, Vinegars, and Spirits, in all Countries.

4. The *second* Experiment will exhibit the common Methods of forcing, or fining down, fermented vinous Liquors, so as to render them expeditiously bright or clear, and fit for Use.

5. The *third* Experiment will shew a Method of converting White Wines into Reds; and of recovering, or improving, the Colour of decayed red Wines.

6. The *fourth*, a Method of concentrating Wines, Vinegars, or Malt-Liquors, for Carriage, or Exportation.

7. The *fifth* will shew a Method of recovering prick'd Wines.

8. The *sixth* and last will shew a more profitable Method, than that commonly used in *England*, of fermenting Malt for Distillation, or the Production of common inflammable Spirits.

These Experiments now follow in their Order.

EXPERIMENT I.

To shew the Method of reducing vegetable Juices, cured by Inspissation or Decoction, back to a State fit for affording Wines, Vinegars, and Brandies, by Fermentation; and at the same Time to exhibit a Method of making an artificial *Must*, or *Stum*, as good as the natural, and equally fit for refermenting, fretting, improving, or making Wines, Vinegars, and Spirits.

9. We took three Pounds of white Lump Sugar well cleansed of its Treacle, and melting it

*Artificial
Must pre-
pared.*

* See *Let. X. Exp. III.*

in

in three Quarts of fair Water, added in the boiling half an Ounce of finely pulverized *Rbenish* Tartar; which dissolved with a remarkable Ebulition, and gave a grateful Acidity to the Liquor. Then taking the Vessel from the Fire, and suffering it to cool, we thus procured a *Must*, which in all respects resembled the natural tart and sweet Juice of a white flavourless Grape, when that Juice is well purified, and often racked from its Sediment, in order to make *Stum*. And if our artificial *Must* be stummed, that is matched, or well fumigated with burning Brimstone, after the Manner shewed in our last Lecture *a*), it thus becomes a perfect *Stum*; which may be made of any Flavour, at the Discretion of the Artift.

Uses.

10. This Experiment is so pregnant, that it might deserve to have its Uses explained by an express Treatise *b*). It affords abundant Instruction for improving the Arts of Sweets, Stums, Wines, Vinegars, and Spirits; it likewise affords some useful Instructions about the Nature of sweet and tart vegetable Juices, and the Ways of imitating them by Art. But these Particulars we can only just touch upon for the present.

*The Experiment
how deduced.*

11. The Experiment itself was formed upon the Analysis of the Juice of the Grape before Fermentation; which Juice, to the Senses, appears no other than a saccharine Substance dissolved in Water, with the Addition of a tartarous Acid: And this being fully confirmed by a chemical Resolution, it was hence easy to expect, that if Tartar, which is the natural Salt of Wine, or of any sweet vegetable Juice fermented, could be artificially dissolved in a proper Mixture of Sugar and Water, it would give an exact Resemblance

a) Exp. II.

b See the Appendix to this Lecture.

of

of the thing. Accordingly it was found upon Trial that Tartar might be thus dissolved, so as to communicate an agreeable Acidity to Sugar, and thus to imitate, in great Perfection, the natural sweet Juices of Vegetables, without their particular Flavours: and hence our Experiment discovers to us the Nature, Use, and Perfection of the Art of *Sweets*.

12. By a *Sweet* is understood any vegetable Juice, whether obtained by Means of Sugar, Raisins, or other Foreign or Domestick Fruit, which is added to Wines in order to improve them. Whence we see that the Art of Sweet-Making might receive a high Degree of Improvement, by using pure Sugar as one general wholesome Sweet, instead of those infinite Mixtures of Honey, Raisins, Syrups, Treacle, Stum, Cyder, &c. wherewith the Sweet-Makers supply the Wine-Coopers, to eke out or amend their Wines. For pure Sugar being added to any poor Wine will ferment therewith, improve it, and bring it to a proper Degree of Strength and Vinosity. If the Wine to be thus amended is tart of itself, no Tartar should be added to the Sugar; but if it be luscious or too sweet, then the Addition of Tartar is proper.

*A Sweet
what.*

13. The present Experiment adds no less Improvement to the Art of *Stums*, which may perhaps be hence brought to its Perfection. And here we desire the Men of Business would duly reflect, that wherever Sugars go, there go in a solid form *Stums*, *Wines*, *Vinegars*, and *Brandies*; that is, the actual Matter out of which, by the bare Addition of Water, these several Commodities may be readily prepared. For it is by no Means necessary that Sugars should be imported and exported in a liquid Form, for the making of

Extended.

of Stums, Wines, &c. because it is so easy to add the Tartar and Water in any Port they arrive at.

*Farther
Uses in the
Trade of
Wines.*

14. Our Experiment also points out the Way of perfecting the *Art of Wines*, by reducing the component Matter thereof to a small Bulk, and occasionally, in any Climate, bringing it back with Water into a Must; which Must may be tinged of any Colour, or impregnated with any Flavour, so as to be fermented into a Wine of any Species or Denomination. Thus if a few Drops of the essential Oil of Nutmeg, or Cinnamon, were to be rubbed with a little Sugar into a Kind of *Elæosaccharum* *, and then mixed with our artificial Must, or Stum, the Wine made of it would have a very grateful Odour and Flavour. And so if an essential Oil were procured from the Lees of any particular Wine, and introduced into our artificial Stum, after the same Manner, the artificial Wine would thus have the Odour and Flavour of the natural Wine that afforded the Lees; bating for the Roughness, Hardness, or Dryness given by the Husk and Stone. For our artificial Must has no Flavour or Colour of its own, but readily receives and becomes impregnated with either by Art. And how far this Experiment may be useful in teaching a Method of making a rich concentrated Wine, for the extemporaneous Improvement of the poorer Sorts, or for making a serviceable Kind of extemporaneous Wine, barely by mixing with Water, we recommend to the Trial of those who have a Talent at this Kind of Experiments.

*And Vine-
gars.*

15. The Art of *Vinegar-Making* may also possibly receive a high Degree of Improvement by Means of the present Experiment, as it affords us a Method of dissolving Tartar in Water, on which the whole Art of Vinegar-making seems to

* See hereafter, *Lect. XIII. Exp. IV.*

depend

depend. For there are many physical and chemical Reasons and Experiments, to shew that Vinegar is no more than a particular Kind of fluid Tartar. And the Art of making Vinegar would then be perfect, when it could readily, or extemporaneously, prepare and concentrate the Commodity; so as to give it a Kind of solid or consistent Form, which should render it durable, bring it into a small Bulk, and leave it fit to be reduced by Water into a fluid Form, for Use in all Climates.

16. We plainly see that the original component Matter of Vinegar, which is Sugar, lies in a small Bulk, and may be readily converted by Water, Air, and Heat into Vinegar *. Sugar in the Act of *Acetification* seems wholly converted into a fluid Tartar; and if the aqueous Liquor be separated from Vinegar, we find the Vinegar is thereby rendered the stronger: infomuch that if Vinegar were to be highly concentrated by Congelation, it would become almost solid, or a Kind of actual Tartar. Whence the Rule is easy, that in order to make an almost solid Vinegar, we should endeavour to dissolve Tartar in an aqueous Liquor. Whence, for perfecting the Art of Vinegar-Making, we recommend the dissolving of Tartar largely with Sugar, or Treacle, and the strongest Vinegar, by repeated Imbibitions, Heat, and a proper Management.

17. We proceed to shew some Use of our Experiment in the Art of Distillation; which Art likewise might possibly arrive at Perfection by its Means. It is generally known that a tasteless, flavourless, yet perfectly vinous and cheap Spirit, is the grand *Desideratum* in the Art of Distilling: Now such a Spirit seems easily procurable from our Stum, made highly acid by the Addition of

In the Distillation of Spirits.

* See *Let. VI. Exp. II.*

Tartar,

Tartar, and fermented till that Acidity prevails, as it soon will do, so as to prove a true Vinosity. And thus a highly vinous, yet flavourless Spirit, may be obtained at a very reasonable Charge, if a Man thoroughly understands the Art of Fermentation. And such a Spirit might be readily flavoured and converted into French Brandy, Arrack, or any other Kind of Spirit, that commonly sells for a much greater Price *a*).

*Farther
Uses.*

18. These Particulars, with several others that might be mentioned, hold of our Experiment in its perfect State : for to reduce sweet vegetable Juices to a pure white Sugar, without any Participation of Treacle, is an extremely *perfect Curation*, which cost much Labour before it was discovered. But now the thing is common, we seem almost to neglect it ; at least do not enquire into the farther Uses of so capital a Discovery, to the apparent Detriment of the Sugar-Trade, and the Colonies thereon depending.

19. Tho' Curation by bare Decoction, or Infusation, is of a lower Class, yet still it has its Uses *b*) ; for even Treacle is an useful Substance : But the Rob of Malt, as we shewed in our last Lecture *b*), may be employed for the making of Beer, Ale, Vinegar, and Spirit, in all Climates, after the same Manner as we here use Sugar. And the Perfection of this Curation would be, to reduce all such Robs to an actual Sugar ; as with skill might be done, we apprehend, to Advantage. Tho' as some Countries and Palates prefer Malt-Liquors and Corn-Spirits, to Wines and the finest foreign Brandies, this Art of Sugar-Making need not be universally extended to Malt and Grain.

a) See hereafter *Leß. XII.*

b) See *Leß. X. Exp. III.*

20. Many other Uses are derivable to Arts and natural Philosophy from our present Experiment; but we have only Time to mention one more. We see that Stums, Wines, Vinegars, and inflammable Spirits of all Sorts, may be commodiously obtained by its Means; we now add, that the original Matter of them all may be reduced to a brown, thick, treacly, or other coloured Substance, whether red, yellow, or black, and exported under this disguised Form to any trading Part of the World, for preparing these Commodities there. And thus the Country possessed of Sugar, might advantageously supply many others with Matter for exercising of several Arts; such as the Production of Wines, Beers, Vinegars, and Brandies. And in the same Manner might Families be supplied with an artificial Must, Stum, or Rob of Grapes, for making any Sort of Wine at home, with much greater Ease than they now brew Beer: for the expert Artist will easily give the proper Flavour and Colour of any Wine *, to this artificial Must, or Rob; so that there should be nothing more required at home, for the making it into Wine, than to add the Water and the proper Ferment in the Cask.

EXPERIMENT II.

The common Method of Forcing or Fining down fermented vinous Liquors, so as to render them expeditiously bright or clear, and fit for Use.

21. We took an Ounce of fine Ising Glass beat *Wine* with a Hammer into Shreds, and dissolved it by *fined.* boiling in a Pint of Water, so that it became a stiff Gelly when cold. Some of this Gelly we whisked

a) See above, §. 12. and hereafter Exp. III.

up into a Froth, with a little of the Wine intended to be fined; then stirred it well among the rest in the Cask, and bunged it down tight. By this Means the Wine will usually become bright in eight or ten Days.

Uses.

22. This Method is best suited to white Wines; but for red ones, the Wine-Coopers commonly use the Whites of Eggs, beat up to a Froth, and mixed in the same Manner with the Wines. And these are the common Methods of Forcing at present used in the Wine-Business.

Rationale.

23. The physical Reason of the Experiment is this, that the Bodies here employed as the Forcing are viscous or glutinous, so as to entangle themselves among the flying Lee, or light Feculencies, that float in the Wine; and thus forming a Mass specifically heavier than the Wine, sink thro' the Body thereof, like a Net, carrying down all the Foulness they meet with in their Way. But when the Wine is extremely rich, so that its specific Gravity proves greater than that of the Mass compounded of the *Forcing*, as it is called, and the Dregs or Lee, this Mass rises upwards, and floats on the Top of the Liquor, in which Case also, the Wine will draw off fine.

Inconveniencies of the Method.

24. The principal Inconvenience of this Method of fining Wines is its Slowness, as not having its Effect in less than a Week, or sometimes a Fortnight, according as the Weather proves favourable or unfavourable, cloudy or clear, windy or calm; which appears to be Matter of constant Observation. But the Wine-Merchant frequently requires a Method that shall with Certainty make his Wines fit for tasting in a few Hours. And a Method of this Kind there is, but kept as a valuable Secret in a few Hands. Perhaps it depends upon the prudent Use of a tartarized Spirit of Wine and the common Forcing, as Accessories, along

along with *Gypsum*, or calcined Alabaster, as the Principal ; all which are to be well romaged, or stirred together in the Wine, for half an Hour, before it is suffered to rest.

25. Let it be here observed that all Wines, *Fining not*
Malt-Liquors, and Vinegars, which are well *always ne-*
made and perfect in their Kind, will grow fine *cessary.*
of themselves barely by standing ; so that if they
do not thus grow fine in a reasonable Time, it is
a Sign they labour under some Disease, that is,
are either too aqueous, too acid, too alkaline,
tend to Putrefaction, or the like. In all these
Cases, which may be properly enough called the
Diseases of Wines, suitable Remedies are required
before the Wines will grow fine.

26. To enquire particularly into the Diseases *Diseases of*
of fermented Liquors, with their respective Cures, *Wine how*
is not the present Design *a)* ; only we must ob- *cured.*
serve, that the most general Remedy hitherto
known for all the Diseases of Wines, is a pru-
dent Use of a tartarized Spirit of Wine, which
not only enriches, but disposes all ordinary Wines
to grow fine. But Wines well prepared from ar-
tificial Must, in the Method above-mentioned,
are subject to no Diseases. And even those ob-
tained in the common Way may be effectually se-
cured, against all Diseases, by Congelation, which
takes away their superfluous Water without Pre-
judice to their vinous Parts *b)*.

27. Skimmed Milk likewise is a proper For- *The Use of*
cing for all white Wines, Arracks, and small Spi- *Milk in*
rits ; but improper for red Wines, because it dis- *Wines.*
charges their Colour. Thus if a few Quarts of
well skimmed Milk be put to a Hogshead of red
Wine, it will soon precipitate the greatest Part

a) See the Appendix to this *Lecture*.

b) See below *Exp. IV.*

of the red Colour, and leave the Liquor much paler, or almost white. Whence this Experiment sometimes becomes of Use in turning pricked red Wines into Whites, where a small Degree of Acidity is not so much perceived. And on this Property of Milk depends that other, of Kin thereto, whereby it whitens Wines that have acquired a brown Colour from the Cask, or by hasty Boiling before they were fermented: For in these Cases, the Addition of a little skimmed Milk will also precipitate the brown Colour, and leave the Wines almost limpid, or of what they call a *Water Whiteness*; which is much coveted abroad in white Wines as well as in Brandies.

EXPERIMENT III.

A Method of converting White Wines into Reds; and of recovering the Colour of decayed red Wines.

*White
Wine
coloured
red.*

28. We put four Ounces of what is commonly called *Turnsol Rags* into an earthen Vessel, and poured upon them a Pint of boiling Water; then covering the Vessel close, and suffering it to cool, we strained off the Liquor, which we found of a very deep red Colour, inclining to purple; so that a small Proportion thereof would give a beautiful bright red, to a large one of white Wine mixed therewith.

*The Expe-
riment
improved.*

29. For keeping, this Tincture might be mixed with Brandy, or made into a Syrup with Sugar; but the usual Way with the Wine-Coopers and Vintners is to infuse the Rags cold in Wine, for a Night or more, and then wring them with their Hands. The Inconvenience of this Method is, that it gives the Wine a disagreeable Taste, or what is vulgarly called the *Taste of the Rag*:
whence

whence the Wines thus coloured usually pass among the Judges for *pressed Wines*, that have got this Taste from the Canvas Bags in which the Lees were pressed.

30. The Way of infusing the Rags in boiling Water is not attended with this Inconvenience; but then it loads the Tincture with Water, which may prove prejudicial to the Wine; or if made into a Syrup, or mixed with Brandy, the Colour is thus diluted, or weakened; so that a large Quantity of these additional Ingredients comes to be used with a small one of the Colour, tho' that alone be the Thing required.

31. Hence the Business of colouring Wines red is attended with considerable Inconveniencies, in those Countries that do not afford the *tinging Grape*, which yields a Blood-red Juice, and with which the Wines of *France* are often stained. In Defect thereof at *Oporto* they sometimes use the Juice of Elder-Berries, and sometimes Logwood, when their Wines are not naturally red enough; for this Colour, it seems, they must have, to make them saleable.

32. The Colour afforded by our present Experiment is not properly the *Port*, but the *Bourdeaux-Red*, which does not so well suit with *Port-Wines*: Whence the Foreign Coopers are often distressed for Want of a proper Colouring to their red Wines in bad Years. We would, therefore, recommend to them the Use of an Extract made by boiling *Stick Laque* in Water; which gives a rich Red, that comes tolerably cheap, and is, perhaps, the perfect red *Port-Colour* *. But if this proves unsatisfactory, let a Method be tried of making a Laque out of the Skins of the ting-

*) See hereafter *Let. XIV. Exp. II.*

ing Grape, or *Raisin de Teinte*. Cochineal might likewise answer the Purpose, tho' it loses of its Colour by mixing with all acid Wines. Elder-Berries give this Colour in a tolerable Degree, but not without communicating a nauseous Flavour.

33. The Produce of our present Experiment might answer well, if the Colour could be had pure, or made up into Cakes, without being imbibed by Rags; for it is very easy to obscure its too great Brightness, or vivid purple Briskness, by the Addition of a little burnt Sugar, Rob of Sloes, Rob of Oak, Rob of Wine, or any other Colour bordering upon the Tawny, so as to make a true *Port-Colour*.

EXPERIMENT IV.

A Method of condensing or concentrating Wines, Vinegars, and Malt-Liquors, for Exportation.

*Wines and
potable
Liquors
improved
by Freez-
ing.*

34. We took a Quart of ordinary red Port-Wine, included in a *Florence* Flask, and placing the Flask in a Mixture of one Part common Salt and two Parts Snow, or beaten Ice, we found the more aqueous Part of the Wine was soon turned to Ice; from which, by a bare Inclination of the Glass, the thick, rich, or more vinous Part of the Wine, was easily drained.

*The Expe-
riment
regulated.*

35. This Experiment is here performed too quick, so that some of the thick and valuable Parts of the Wine are caught and detained in the Ice. To perform it in Perfection, the natural freezing Cold should be employed; by which Means, Wines, Vinegars, and Malt-Liquors may be

be reduced to a fourth of their ordinary Bulk, without any considerable Loss of their essential Parts; little more than the useless, or detrimental Water being thus separated, so as to leave all the essential Parts of the Wine admirably cured, or capable of remaining perfect, for several Years, as has been found upon Trial. And by a prudent Use and Application of this Experiment, we conceive that great Improvements might be made in the Wine-Trade.

36. For by a proper Contrivance, and a little Dexterity, which may be easily gained by Experience, large Quantities of the poorest Wines might be thus, at little Expence, converted into rich ones, so as to increase their Value in Proportion to the Diminution of their Bulk. And thus also, by repeating the Operation, might extremely rich and generous Wines, or a true Quintessence, be procured, for the Amendment of the thinner and poorer Sorts. And in this View it should be remembered, that mountainous Wine-Countries are often furnished with Snow, by means whereof artificial Freezing might be practised in the time of Vintage; the bare intimation of which may give a sufficient Hint for introducing a new and useful Branch of Business, as Wines may be hence concentrated after Fermentation, no less commodiously than the Juice of the Grape before that Operation *a)*. And if to this be added, that the *Art of Congelation* is also capable of Improvement from a proper Use of *Sal-Ammoniac* and Water *b)*; for, as the *Sal-Ammoniac* remains easily recoverable, it should seem that little more than a suitable Apparatus is required to bring this

a) See *Let. X. Exp. III.*

b) See *Let. V. Exp. II.*

Business to Perfection, with all desirable Advantage.

EXPERIMENT V.

A Method of recovering prick'd Wines.

*Prick'd
Wine re-
covered.*

37. To a Bottle of prick'd red *Port-Wine* we added about half an Ounce of tartarized Spirit of Wine; then shaking the Liquor well together, we set it by for a few Days, expecting to find it remarkably altered for the better; as upon Trial it appeared indeed to be.

38. This Experiment depends upon the useful Doctrine of *Acids* and *Alkalies* *a*). All perfect Wines have naturally some Acidity; but when this Acidity prevails too much, the Wine is said to be *prick'd*, which is a State thereof tending to Vinegar *b*). But the prudent Introduction of a fine *alkaline Salt*, such as that imbibed by Spirit of Wine digested upon Salt of Tartar, (for so the tartarized Spirit of Wine is prepared) has a direct Power of taking off the Acidity; to which Effect the Spirit of Wine also contributes, and is in other Respects a great Preservative of fermented Liquors *c*). And if the Operation be dextrously performed, prick'd Wines may be thus recovered, and made to remain sound and saleable for some Time. The same Method is likewise applicable to *hard Malt-Liquors*, or such as are but just turned sour, and not near becoming Vinegar.

39. An Expedient of the same Nature is frequently made use of to recover sour Small-Beer,

a) See these Terms explained in the *Glossary* prefixed to our *Lectures*.

b) See *Leß. VII. Exp. II.*

c) See *Leß. VII. Exp. IV.* and the Appendix to the present *Lecture*.

by

by adding thereto a little Chalk or Powder of Oyster-Shells; for Chalk and Oyster-Shells being terrestrial Alkalies, immediately take off the too great Acidity of the Liquor, and causing an Ebullition therewith, give it a considerable Briskness, if drank before the Ebullition is entirely finished. In order to continue it the longer, 'tis best to add the Chalk, or Oyster-Shells, whole to the Liquor in the Cask; but Care must be taken to drink it out soon, otherwise the Liquor will spoil *a*).

EXPERIMENT VI.

A more profitable Method, than the common, of fermenting Malt for Distillation, in order to obtain from it a Brandy, or inflammable Spirit.

40. We took ten Pounds of Malt reduced to a fine Flour, and three Pounds of common ^{Brewing} Wheat-Meal; to these we added, first, two ^{for Distil-} Gallons of cold Water, and stirred them very well together; then five Gallons of Water boiling hot, and stirred all very briskly again. Letting them now stand for two Hours, we repeated the Stirring again, and when the whole was grown cold, we added to it two Ounces of solid Yeast, and set it by in a warmish Place, loosely covered, to ferment *a*).

41. This Experiment exhibits the *Dutch* Method of preparing the *Wash*, as it is called, for Malt-Spirit, whereby they save much Trouble, and procure a large Yield of Spirit; thus commodiously reducing the two Businesses of Brew-

a) See *Lett. VII. passim.*

ing and Fermenting, to a single Operation. In *England* the Method is, to brew and mash for Spirit just as they ordinarily do for Beer; only instead of boiling the Wort, they pump it into large Coolers, and afterwards run it into their fermenting Backs, to be there work'd, or fermented with Yeast; thus bestowing twice as much Labour in the Operation, as is required; and at the same Time losing considerably of their Quantity of Spirit, by leaving the gross Bottoms out of the Still, for Fear of burning.

And Advantages.

42. In the Manner of our present Experiment, where the Malt is ground fine, we have all its fermentable Parts set loose, so as at once to mix with the Water. And we can thus put all the *Bottoms* into the Still, without Danger of burning; because being rendered so fine at first, they entirely lose their Clamminess in the Fermentation, so as to become light or buoyant, and thus increase the Yield of the Spirit.

Regulation.

43. The Meal of unmalted Corn is found necessary to be mixed along with the Malt, to prevent its over-fermenting, and throwing off the Matter of the Spirit. But as Dispatch is here particularly required, to avoid Expence and a large Apparatus of Vessels, a considerable Quantity of Yeast is added to quicken the Fermentation, so that it may be finished in two or three Days.

44. More Yeast should be added if the Weather be cold, and less if it be hot; the Converse is to be understood of Meal, more whereof is required in hot Weather to check, and less in cold, to hasten the Operation; which in the present Case is designed to be violent, contrary to what ought to be observed in the Fermentation for Wines, where the slower the Operation is performed, the better the Liquor will prove. Which Rule

Rule may likewise obtain here in a less Degree: for it is possible to ferment the Wash so violently, that it shall soon end in Putrefaction *a*). And thus by rightly conducting the several Parts of the Process, we may, by Distillation, procure all the Spirit that Malt and Meal are capable of affording by Fermentation. The Method of procuring this Spirit will be shewn in our next Lecture *b*).

AXIOMS and CANONS.

1. We have seen in the preceding Enquiry, that excellent Stums, Sweets, Wines, Vinegars, and Brandies, may be prepared from Sugar, in any Climate, where Water and Tartar can be procured *c*).

2. That Malt-Liquors, and Malt-Vinegars, may be commodiously prepared in any hot Climate, from the *Rob* or Treacle of Malt; which is fit for Transportation, so as to convey the desired Virtue of the Malt in a small Bulk, and retain it perfect for several Years *d*).

3. That the Perfection of the *Art of Vinegar-Making* depends upon the Conversion of Sugar into a fluid Tartar; or a Method of permanently dissolving a large Proportion of Tartar in Water *e*).

4. That it is possible to reduce both Wines and Vinegars to a thick Syrupy Form *f*) : since the

a) See *Leç. VII. passim*.

b) See *Leç. XII. Exp. I.*

c) See *Exp. I.* See also *Leç. VII. Exp. I.*

d) *Exp. I.* See also *Leç. X. Exp. III.*

e) See *Exp. I.* See also *Leç. VII. Exp. II.*

f) *Exp. I, IV.*

original Matter of them both, *viz.* Sugar, is solid, and since they both may be concentrated by Frost to a high Degree of Richness and Thickness.

5. That a new Art may be introduced of supplying Foreign Countries with a proper, or rich, syrupy, or treacly Substance, which shall lie in a small Compass, for the making of Wines, Beers, Vinegars, and Spirits, in all Climates, with considerable Advantage *a)*: A Consideration deserving the Attention of the Sugar-Colonies, or their Mother-Kingdoms.

6. That the sweet and tart Juices, as those of Summer-Fruits, Cherries, Grapes, &c. consist of a saccharine and tartareous Substance; or, to speak explicitly, of an actual Sugar, and an actual fluid Tartar: which affords an useful Rule for improving these natural Juices in bad Years, and again for imitating them by Art; as also for producing Wines, Vinegars, and Brandies, without them, where Sugar and Tartar can be procured *b)*.

7. That there is a great Affinity betwixt Sugar and Tartar, since they not only reside together, and are intimately mixed in all sweet and tart vegetable Juices, but also seem readily convertible into each other; for the acid and tart immature Juices of Plants become saccharine by Ripening; Wine made wholly of Sugar and Water shoots a large Quantity of Tartar; and Sugar is wholly convertible into Vinegar, which is a fluid Tartar. Whence much Light might be derived for explaining the Nature of Vegetation, Acidity, Sweetness, Immaturity, Ripeness, Vi-

a) Exp. I, IV. See also *Lect. X. Exp. III.*

b) Exp. I. See also *Lect. VII. and X. passim.*

nification, Acetification, and the Art of procuring Tartar *a*).

8. That the Improvement, or Perfection, of several Arts may depend upon a single Experiment; as we remarkably see by our simple Experiment of dissolving Tartar in Water and Sugar *b*); which has a direct Tendency to improve the several Arts of Sweets, Stums, Wines, Vinegars, and Spirits.

9. That a very large Proportion of Water enters the natural Composition of Stums, Wines, Vinegars, and Spirits *c*); as plainly appears from hence, that the essential Matter of them all is contained in dry Sugar, which being barely dissolved in Water, and fermented, becomes Wine; or a Liquor that may, by Congelation, be reduced to a fourth, or a sixth Part of its natural Bulk, without any considerable Loss of its valuable Part, or of little more than its superfluous Phlegm or Water *d*).

10. That the Diseases of Stums, Wines, and Vinegars, are owing to an Over-Proportion of aqueous Parts; so that if their Water be taken away, without doing Violence to the essential Matter, those several Commodities may be preserved in a State of Perfection; as we see they actually are by Concentration, or Congelation, which thus advantageously separates their aqueous Parts without hurting the rest *d*).

11. That numberless new Sorts of Wines and Brandies are producible, barely by adding any well-scented Vegetables, or their essential Oils, or a

a) See *Lib. VII.* and *X.* See also the present *Lecture*, *Exp. I.*

b) *Exp. I.*

c) *Exp. I.* and *IV.*

d) See *Exp. IV.*

Mixture of such Oils, to a natural or artificial Must in the Fermentation *a*). And the same may be proportionably understood of the Colours of Wines; which might, by proper tinging Ingredients, be thus procured blue, green, yellow, or of other Colours, if it were necessary, as well as pale, or red *b*).

12. That the physical Agent in the Fining of Wines, and other fermented Liquors, is some proper viscous Substance, which entangles the gross Particles, and either sinks with them to the Bottom, or rises to the Top, so as to separate and keep them separate from the Body of the Liquor; and that, on this Foundation, better Methods of fining may be discovered, than those hitherto commonly known and practised *c*).

13. That *tartarized Spirit of Wine* is a Remedy for acid Wines, and not only abates their Acidity, but also strengthens, and disposes them to grow fine, when they are thick and turbid *d*).

14. That Milk, deprived of its Cream, will discharge the Colour of red Wine, by precipitating the tinging Matter to the Bottom; and so likewise lessen, and take off the brown Colour, wherewith white Wines are sometimes accidentally tinged *e*).

15. That the Business of colouring red Wines artificially may be improved by a proper Use of an artificial Turnsol without Rags; such as an Extract of Stick-Laque, &c. but particularly an artificial Tincture of the Husk or Skin of the red Grape, or a particular Laque made from the *Raisin de Teinte* *f*).

a) Exp. I. See also *Leç.* VII. Exp. I.

b) See Exp. III.

c) Exp. II.

d) Exp. V. See also the Appendix below.

e) Exp. II.

f) Exp. III.

16. That

16. That it is in the Power of Art greatly to accelerate the Operation of vinous Fermentation, so as to finish the whole in a few Days Time: But that this should be done only when a Spirit, and not a Wine, is intended; because such a hasty Fermentation subverts or destroys the Texture requisite in vinous Liquors *a*).

APPENDIX to LECTURE XI.

S E C T. I.

The Theory of Vinous Fermentation.

1. The extensive Doctrine of Vinous Fermentation being little regarded, in Proportion to its philosophical and practical Uses, it may be proper in this Place to lay down its *Theory*, after a concise axiomatical Manner (as we are the better enabled to do from the Labour which Dr. *Stahl* has bestowed upon this Subject *b*) and subjoin a few Observations with regard to Practice.

2. *Vinous Fermentation* is an intestine Motion performed by the instrumental Efficacy of Water; so as to strike asunder, attenuate, transpose, and again collect and recompose, in a particular Manner, the Salt, Oil, and Earth of a fermentable Subject *c*).

3. Fermentable Subjects, therefore, are mixed Bodies; consisting of *Salt*, *Oil*, and a *Subtile Earth* *d*).

4. These compound Particles of all fermentable Subjects are so small, that when asunder they become imperceptible to the Senses; for

a) See Lect. VII. *passim*. See also the present, *Exp. VI.* and the following *Appendix*.

b) See his *Zymotechnia fundamentalis*.

c) Consider all the *Instances*, or what seems equipollent to them all, Sugar and Water.

d) Into which all fermentable Substances are resolved by a chemical Analysis.

neither

neither the Touch nor the Sight distinguishes them: Whence being mixed with an aqueous Fluid, they leave it transparent. Neither have fermentable Bodies any considerable Smell or Taste, besides the Taste of Sweetness.

5. These *Principles* of Fermentation, viz. the Salt, Oil, and Earth, must of Necessity be in a compound State; for Separation presupposes Connexion *a*). And by Composition is not here understood bare Juxta-position, but a very intimate Cohesion of the small and different Particles: So that the Salt, Oil, and Earth, in each of these little and insensible Compounds, are in actual Cohesion, Connexion, and Union.

6. When, therefore, any one of these *Principles* abounds in an Over-Proportion for an intimate Union, the whole Efficacy of the Fermentation is either stopped and impaired, or else presently determined. and limited to one certain Species.

7. And this is to be particularly remarked of the volatile or essential Oil; which being in an Over-Proportion for an intimate Union with the rest, rather hinders than promotes vinous Fermentation, but greatly disposes the Subject to Putrefaction *b*).

8. But if the Salt predominates, this does not so much prevent the Success of the Fermentation, provided it be in some Kind of Connexion with the oily and earthy *Principles*: And if it be not thus connected, it is readily taken, by Solution in the Water, from the other duly mixed Portion, and thus, in some Measure, promotes and assists the Operation.

9. This equable Connexion of Salt, Oil, and Earth into a single compound Particle, makes a

a) See above §. 2.

b) As in Mace, Cloves, Nutmeg, &c.

Corpuscle soluble in Water; that is, this compound Corpuscle is, by Means of its saline Particle, connected with the aqueous Corpuscles, and moved up and down therewith; that is, it becomes dissolved therein.

10. Where these compound Corpuscles are not thus connected with the Water, many of them join together either into a gross Matter *a)*, or into a loose, chaffy, or spongy one *b)*.

11. When diluted with a little Moisture, these compound Corpuscles feel slippery, clammy, and unctuous to the Touch, and after the like Manner affect the Taste with a rosy Sweetness or Insipidity *c)*.

12. When undisturbed, and left to themselves, they preserve their mutual Cohesion, and their solid or dry Consistence, without Alteration *d)*.

13. But as soon as an aqueous Fluid is put to them, there presently begins a Commotion, and afterwards a subtile Separation among them.

14. This Commotion and Separation first begins in the whole Substance *e)*: for before Water is added, the Subject may remain in dry, solid, and large Pieces *f)*; which being reduced to Powder, each Grain thereof is an Aggregate of many lesser compound Corpuscles; and these being put into Water, dissolve and separately float therein, till at Length they become so small as to be invisible, and thicken the Consistence of the Liquor.

15. When the compound Particles are thus separated from one another, they are next gra-

a) As in the Lees of Wine.

b) As the Grains in Brewing.

c) As appears in all Instances.

d) Consider Malt, Raisins, Sugar, and all the Instances.

e) As when Sugar dissolves in Water.

f) As in Malt, Sugar, &c.

dually separated from their own different Parts, that is, the different Particles whereof they consist, *viz.* the Salt, the Oil, and the Earth, are disjoined from one another by the Interposition of the Particles of Water.

16. The first Commotion is no more than a bare Solution, when the Water lays hold of the saline Parts of the compound Corpuscle, and thus carries them about with itself. For of these several *Principles* the saline one soonest dissolves in Water.

17. But the succeeding Separation, *viz.* the *fermentative Motion*, is a different Thing, and what disentangles the oily and earthy Parts from the saline, partly by the Impulse of the others in their Motion, and partly by the Force of the aqueous Particles that are now continually meeting and dashing against them.

18. This Motion is performed by the Water, as a Fluid, or Aggregate of an infinite Number of Particles, in actual and perpetual Motion; their Smallness being proportionable to that of the fermenting Corpuscles, and their Motion, or constant Susceptibility of Motion, by Warmth and the Motion of the Air, disposing them to move other subtile, moveable Corpuscles also.

19. But more particularly, an aqueous Fluid gives this Commotion, by the certain Agreement of Figure and Size which its Particles have with those of the *Salt* of the fermentable Subject: Whence they come to be readily and closely applied together, so as to move almost like one and the same compound Corpuscle; whilst the Water is no way disposed to cohere immediately with the Oil or Earth. And thus an unequal Concussion is made in the compound Corpuscles of the Subject; which Concussion at length

length striking out the saline Particle, and loosening the others, brings on a Separation of the original Connexion of the Subject.

20. Thus if, instead of Water, an oily Fluid were poured upon any fermentable Subject, no vinous Fermentation would ensue; as the Oil can neither give a sufficient Impulse to the compound Corpuscles, which are grosser than its own constituent Particles, nor force away the oily or saline Particles of the Subject from the Connexion of the others, which detain, and as it were envelope or defend them, from its Action.

21. Hence an *aqueous Fluid* alone is the true *Instrument* for procuring a fermentable Motion to these mixed Corpuscles of the Subject.

22. As the small Parts of this aqueous Fluid are in a perpetual Motion, and by Means thereof affect the compound Corpuscles of the Subject, a certain Degree of this Motion is required, which principally depends upon external Heat.

23. It is true, a considerable Degree of cold will not absolutely prevent all Fermentation, though it will greatly retard it; and a boiling Heat will prevent it still more. The due Heat therefore for promoting and quickening the Operation, is a tepid one, or the mean betwixt the two Extremes of Freezing and Boiling.

24. The Admission of the Air also, though not of absolute necessity, yet greatly promotes and quickens the Action, as being a capital *Instrument* in the Moving of oily Particles, and the true Analyser of oily Subjects, in Concurrence with the Motion of Fire *.

25. But whilst the Air thus contributes to hasten the Effect, it at the same Time, by its Activity,

* See Lect. II. Exp. III. IV.

Activity, causes some remarkable Alterations in the oily Part; as being capable not only of moving, but of absolutely dissolving and displacing it from its original Connexion, and thus carrying it off with itself from the whole Mass *a*).

26. And hence, though the Consideration of the Air does not in the general so properly belong to Fermentation, yet it does in particular; as having an accidental Power to alter every Species of this Operation: Whence its Agency ought to be well understood, in order either to procure desirable Alterations in the fermenting Mass, or to prevent and correct such as are not eligible.

27. The *oily Principle*, which the Air thus separates and dissolves, is also elastic, though it probably has that Property from its Intercourse with the Air itself, added to an extreme Subtility of Parts; so that a small Bulk thereof containing a large Number of individual Particles, may fill and satiate a large Bulk of Air *b*).

28. To proceed: When an *aqueous Fluid* is added to a fermentable Subject, exposed to a temperate Heat, and in some small Degree to the open Air, a fermentative Struggle immediately arises; the Water by its continual intestine Motion dissolving the saline Part of the compound Particles, and carrying them up and down with itself infinite Ways, amidst innumerable other Particles, as well merely aqueous as fermentable ones: Whence, by this Collision and Attrition, the oily and earthy Particles are at length sepa-

a) As may appear by the Loss of Spirit and Flavour in open Fermentation, where the Matter is exposed to too much Air.

b) As in the Atmospheres of odoriferous Vegetables; and again in Perfumes or strong-scented Drugs; as Musk, Ambergrase, Camphire, Asa-fetida, &c.

rated and disjoined from their Connexion with the saline.

29. The oily Particles, as being the most subtile, and most disposed for *elastic Motion*, would thus be thrown up to the Surface of the Liquor, and carried off by the Air, if they were not long involved or enveloped in the earthy ones; which are not only undisposed and unfit for Avolation, but also strongly inclined to form larger Collections or Aggregations with other earthy ones, and so sink with them to the Bottom *a*).

30. But before this can be fully brought about, that is, before many of the earthy Particles are gradually collected together by their frequent Occursions, so as to form a Bulk that can be no longer moved about by the aqueous Fluid, it happens that, by these repeated Collisions, some of the oily Particles (now disjoined from the saline ones, which are strongly agitated by the aqueous Particles, and separated from the earthy ones) are again, by Degrees, more intimately connected with the saline ones; whilst, on the other Hand, these same saline Particles imbibe and take to themselves some of the earthy ones, which being left single, upon their Separation from the oily Particles, floated separately about in the Fluid *b*).

31. And hence proceed the several different Consequences of Fermentation; *viz.* (1) From the Extrication of the saline Particles of the Subject proceeds the tart, saline, or acid Taste of

a) In the Form of Lees or Sediment.

b) Observe that this whole Doctrine is not delivered as hypotheticalal, but as derived from a careful Consideration of all the *Instances*, both *à priori* and *à posteriori*, in the Way of a just *Induction*.

the Liquor; which is more sensible at first, before the Liquor is duly composed and settled, or the new Arrangement and Connexion of the saline Particles with those of the oily and earthy Kinds compleated: After which the Liquor proves milder, softer, or less pungent. (2) From the oily Particles being set at Liberty, proceeds the strong Smell of the Liquor, and the Head or the shining Skin upon the Surface. (3) The earthy Particles collecting together in Clusters, cause the Fluid first to appear turbid, and afterwards to precipitate a visible earthy or clay-like Matter: And some of these earthy Parts in their Motion arriving at the Head or oily Skin on the Surface, cause it to thicken, and afterwards carrying it down along with them, thus constitute the *Lees* which abound in Oil. (4) From this Struggle or Collision, which is productive both of Solution and a new Connexion in the saline and earthy Corpuscles, proceeds the *Ebullition* in Fermentation. And lastly, by the same repeated Collision of the oily with the aqueous and saline Particles, the *inflammable Spirit* is produced *a*).

32. *Water* performs this whole Series of Changes, by becoming the Instrument and *Medium* of new Separations, Transpositions, and Combinations; as also preserving these new Combinations after they are made, by a Kind of constant Interposition, or essential Concurrence *b*). For Wine cannot, without extreme Alteration, be deprived of all its Humidity; though it may be freed from the superfluous Part thereof by Congelation, without the least Prejudice *c*).

a) See *Lect. VII. Exp. IV.*

b) See *Lect. XI. Exp. IV.*

c) This appears to be true in Fact.

33. And although the aqueous Humidity were intirely taken away, yet the fermented Matters would still retain and respectively shew the Alteration brought upon them; for the Spirit, with its essential Aquosity, would appear in one Place, the acid Salt in another, and the dry Earth, or unctuous *Fæces*, in a third *a*): And in the two last the aqueous Part may be totally separated, without any way altering the Places or State they were put into by the Act of Fermentation *b*).

S E C T. II.

Practical Observations relating to vinous Fermentation.

1. According to the Doctrine above delivered, every fermentable Subject is in itself, or may be reduced to, a dry and solid Body, consisting of oily, saline, and earthy Parts, so put together as perfectly to dissolve with Water into a transparent clammy Liquor: Whence Malt or other Grain, Grapes or other Fruit, are to have their proper fermentable Parts estimated by the Quantity of dry, pure, fermentable Matter, or Sugar, they would yield; all their other Parts being either chaffy or aqueous, and foreign to the real Purpose of Fermentation.

2. This teaches us a Rule for reducing all fermentable Matters to their least Dimensions, and preserving them at all Times fit and perfect for Use; viz. by making them into pure dry *Sugars*: Which, though at present generally

a) As we see in Tartar, and dry Wine Lees.

b) See *Lect. VII. passim*.

practised upon the Sugar-Cane only, is performable to good Advantage upon other Subjects *a*).

3. The Perfection of Fermentation in general depends upon three Things; *viz.* (1.) the Goodness and Suitableness of the Subject; (2.) the Goodness and Proportion of the Water put to it; and (3.) the Regulation of the Operation.

4. The Goodness of the Subject in general is determined by its Purity and perfect Solubility in Water, without impairing the Transparency thereof, or changing its Colour. And this Character is excellently answered by the finest Sugar; though the usual Manner of preparing and refining it, by a strong Heat, somewhat indisposes it for a ready Fermentation, which newly expressed and unboiled vegetable Juices are greatly disposed to; whence their Fermentation is much sooner finished.

5. That Water is generally allowed best for Fermentation, which of itself contains most fermentable Parts; and such is, (1.) the Water that naturally grows along with Fruits; (2.) Rain Water, which is impregnated with vegetable Matters; and (3.) River-Water, which also contains some vegetable Substances; but (4.) Spring Water is the purest and least altered by foreign Mixture: Whence the truest Estimate may be made of a fermentable Subject by its Means, provided it have no Peculiarity contrary to the Nature of Fermentation *b*).

6. The Quantity or Proportion of the Water is limited by the Nature of the Thing. We see that dry fermentable Subjects will never of themselves fall into Fermentation; too little Moisture

a) See *Lect. VII. Exp. I.* and *Lect. X. Exp. III.*

b) See *Lect. V. VII.* and *X.*

disposes them rather to putrify than ferment *; and too large a Proportion scatters and diffuses them, so that the Parts have not their Effect upon each other, and become in a Manner lost: So that there is a certain middle Proportion which is best, and suffers the Whole to ferment freely, and to obtain such a Body and Consistence as will enable it to keep sound and perfect; and this Proportion is about two thirds or three fourths of Water to one of perfectly pure and dry fermentable Matter.

7. The Regulation of the Operation includes, (1) the Manner of putting the Subject to work; and (2) the external Regimen during the Operation. The Subject may be set to work either with or without Addition, and with or without Heating; and this according to the Climate or Season of the Year. The recent expressed Juice of Grapes seldom requires either; but falls immediately to ferment of itself, and finishes the Work in a few Days. But in cold Countries all fermentable Juices require to be quickened by artificial Warmth, and the Addition of a proper Ferment. The Heat should be barely tepid, and the Quantity of Ferment moderate; so as to begin the Operation speedily, before the Liquor receives any Damage from the external Air, or Change of Weather. The Ferment employed must be of the same Nature with the Liquor, or yielded by a fermenting Substance of the same Kind; otherwise it will introduce and impress its own foreign Nature upon the Subject.

8. *Ferments* are those Substances which added to a Liquor prepared for Fermentation, make it begin and end the Operation sooner than it would have done by itself. They consist of

* See Lett. VII.

the most subtle, moveable Parts of the fermenting Liquor, already separated from the grosser or more sluggish ; and are therefore thrown up to the Top of a fermenting Liquor : Whence being taken in their State of fermenting Motion, and added to a fresh Parcel of prepared Liquor, no wonder if they soon set it also in a fermenting Motion. But Care must be had not to use an Over-Proportion, lest instead of quickening the Operation, it should be perverted by too great a Confusion and Disorder ; which if it should happen, can not easily be stopped, nor its Inconveniences be easily remedied.

9. The external Regimen during the Operation regards the Admission or Exclusion of the Air, and the Warmth of the Place. The free Admission of the Air greatly promotes and quickens the Operation, but carries away some of the fine, volatile, unctuous Parts of the Subject, and consequently impoverishes the Liquor : whence the most perfect Way is to exclude the Air, and to perform the Operation in a close Cask, if Expedition be not required. In this Case, a little Space should be left unpossessed by the Liquor at the Top of the Vessel, and then there will be no Danger of bursting it. Indeed this might otherwise be readily prevented, by the Use of a *Valve* to let out the foul Air, which is constantly generated in Fermentation, and if too long detained in the Cask, is apt to be imbibed again by the Liquor, so as to give it a nauseous Taste and Odour. And if the Climate or Season be cold, the Place of the Operation should be kept moderately warm by Fire, or some proper Contrivance ; otherwise the Fermentation may languish, or be checked, before the full Effect is procured.

10. These Cautions being duly observed, the

the Operation will be performed to great Advantage. When it is fully ended, or rather a little before, the containing Vessel must be close stopped up, and kept well secured from the external Air, that the Liquor may, of itself, grow perfectly bright and fine; as it will do, if no Error has happened in the Management. And this is the most perfect Method of fermenting Wines, where the fermentable Liquor is prepared by Art *a*); but other Cautions and Rules are required, when Nature affords the Juice imperfect, or unduly mixed, as in bad Vintages, &c. *b*).

11. But this Method of fermenting close is somewhat slow; and greater Expedition is often required in Practice, insomuch as sometimes to become the primary Consideration. We shall therefore next take a View of the several artificial Means to be used for shortening the Operation, without any considerable Prejudice to the Liquor.

12. The Things that have a principal Tendency to hasten the Business of Fermentation, are, (1) the making of the Liquor sufficiently dilute; (2) the Addition of a large Proportion of Ferment; (3) the keeping the Whole in a due Degree of Warmth; and (4) the free Admission of the external Air.

13. 'Tis a common Observation, that thin Wines finish their Fermentation sooner than such as are rich; as if, for the Sake of Dispatch, they should be made a little thinner than usual. The Defect may be afterwards supplied with Spirit of Wine, and richer Wine, according to the Practice in Wine-Countries when the Vintage proves poor and watery *c*).

a) See *Let.* VII. *Exp.* I. & *Let.* XI. *Exp.* I.

b) See *Let.* VII. & XI. *passim.* *c*) See *Let.* XI. *Exp.* IV.

14. A large Proportion of Ferment has a great Power to forward the Operation, and becomes necessary in making all the artificial Wines, where the vegetable Juice is not recent, or where it has felt the Force of the Fire; unless the Wine be purposely designed to ferment imperfectly, that it may retain its Sweetness, and appear the richer: but this is always with a Loss of Strength or Spirit, which, however, may readily be supplied by the Help of Brandy.

14. Where the utmost Expedition is required, a due Temperature, or tepid Degree of external Warmth, must, by all Means, be kept up by Art, if the Climate or Country does not naturally afford it: For Heat has a peculiar Power of liquifying and thinning all Fermentable Juices, so as to make them work, without lessening their Strength as diluting does; which indeed it rather increases, if it be not too violent, or too long continued.

16. We have already observed, that too free an Admission of the external Air, though it greatly forwards the Operation, yet considerably prejudices the Liquor, by carrying off its finer and more spirituous Part. The free Air, therefore, is to be admitted prudently, and principally at first, in order to excite the fermentative Motion; and this spirituous Part may be afterwards detained, or kept from flying off, towards the End of the Operation, by covering the Vessel close, or giving it but little Vent. And when these several Means are prudently used together, the Operation may be performed with considerable Expedition and Advantage; provided the original fermentable Matter be rightly disposed, or duly mixed of saline or acid, oily, and terrestrial Parts.

17. The *Phænomena* of vinous Fermentation are various, and differ according to the Degree of
of

of the Operation; though the ultimate Effect is generally the same. Sometimes the Fermentation gives manifest Signs of itself; as by Frothing, Hissing, Explosion, &c. and sometimes again scarce any manifest Signs at all; whence we may consider it as an *apparent* or *latent Operation*. The apparent is sufficiently known by its Signs; but the latent has been less regarded.

18. When any fermentable Matter is sufficiently diluted with Water, it has immediately a natural Tendency to Fermentation, and hath often actually fermented and produced a Wine, though a Spectator could neither see, nor well suspect, any fermenting Motion in the Liquor. In this Case, where no Ferment has been used, and the Operation proceeds in its own natural, slow, and silent Manner, there may be commonly seen on the Surface a thin, shining Skin; which, instead of a large, frothy Head in the stronger Fermentation, keeps in the fine Parts, and prevents their Avolation and Escape. Sometimes also a Degree of Hoariness, Finew, or Mouldiness, will appear on the Top, without mixing itself with the Body of the Liquor, or without communicating any ill Taste thereto. And in this Manner a slow and silent Fermentation has been carried on for several Months, without any spirting up of Bubbles, or other common Signs of the Operation; though it has, at last, finished its Course to greater Perfection.

19. And something like this *silent Fermentation* remains for a long Time in the Liquor, after the common *tumultuary Fermentation* is finished, which indeed leaves its Work but imperfect; so that the Liquor afterwards requires a considerable Time to grow fine, ripen, and become fit for Drinking: Whereas in the silent Method

thod, these Ends are all at once carrying on at the Time of the Operation. And here lies a great Part of the Advantage which the slow Way of fermenting close has over the common one.

20. It is observable, that though a small Quantity of Liquor finishes its Fermentation sooner than a large one, yet the larger proves the better; as a great Body of Liquor is not so liable to receive pernicious Alterations, from Heat, Cold, the Air, or other accidental Things. And even where nothing remarkable of this Kind has happened, it is surprizing to note the Difference betwixt a small Quantity and a large one, of the very same Liquor, fermented in the very same Manner, only the one in a small and the other in a large Vessel.

21. Small Wines may be brought to undergo a second Fermentation, by being mixed with proper fermentable Materials; and thus may be rendered stronger and richer, so as to be fit for Exportation, &c. Otherwise it is observed that Wines which finish their Fermentation in eight or ten Days, will not ordinarily endure the Sea.

22. It is a necessary Caution in all Fermentation, to prevent too great external Heat, for Fear of changing the Fermentation to Putrefaction *, and to remove the Wines to a cooler Place, when the Violence of the Operation is over; that they may purge and fine themselves by Degrees, without Danger of turning acid, as they are apt to do in a hot Place. Or if they cannot be kept cool, they ought to be early racked from their Lees; which tends to preserve them sound, and prevents their turning eager, ropy, and foul a).

*) See Lect. VII.

23. It is to be observed of all Liquors prepared by Fermentation, that the Interposition of *Water* keeps not only the saline, oily, and spirituous Parts, but also the mucilaginous and earthy ones, in their due Arrangement and some Degree of Connexion; from which if they are again disturbed, there happens such a Change as cannot well be prevented from proving pernicious, but the Liquor will successively and hastily proceed on to Corruption *a*). Thus if a fermented Liquor be agitated by a great boiling Heat, its proper Arrangement is thereby disordered, and the Liquor not only becomes manifestly thick and turbid, but more saline and austere, through the Separation of the spirituous and oily Particles from the saline ones, wherewith, being before in some Measure connected, their Acrimony was sheathed or abated.

24. Such Liquors tend so much the faster to Alteration or Putrefaction, if they are not carefully looked after and preserved; but especially if, through any great Commotion by Heat, the more intimate Connexion of the spirituous Parts with the saline and mucilaginous, or even with the remaining aqueous ones, be disturbed and broken: Whence either the whole Mass turns to Vinegar, or to a ropy, corrupt, putrid Substance *a*). But if such fermented Liquors are carefully preserved at Rest, and kept from Injuries, they will long remain in a sound and uncorrupted State; as we continually see in Wines and Malt-Liquors.

25. And farther, all these fermented Liquors will be fitted to resist the Alterations of the Weather or

a) See *Lib. VII.*

Seasons of the Year, with respect to Heat, Cold, and a fermenting Humidity in the Air, (which is by some esteemed the Cause of Fretting in Wines) if their superfluous Water be artificially separated from them, so as that the Liquor itself may be concentrated; in which State it will remain for many Years unchangeable, through the Summer's Heat, and the Winter's Cold *.

26. When a chemical Analysis is made of these Liquors, the first Part that rises is *inflammable Spirit*; the next, *Pblegm*, mixed with an Acid, and an essential Oil, leaving a thick Matter, or Rob of Wine, at the Bottom; which, when freed from its superfluous Moisture, is observed to be very durable, and full of Tartar. But the bare Mixing of these several Parts together will not make the original Liquor again: Which shews that they were all before connected in a certain particular Manner, which was dissolved and destroyed in the Act of Separation; and again, that each of these Productions received a particular new Kind of Alteration from that Act of Separation, which will not suffer them to reunite as before, without some proper intermediate Substance, or a new Fermentation.

27. Hence pure Wine consists of much Water, a moderate Quantity of inflammable Spirit, a little essential Oil, a Proportion of acid Salt, and a certain mixed Substance, or Rob, called by *Becher*, the *media Substantia Vini*. And whilst these several Parts remain firmly united together in their due Proportion, the Wine is in its perfect State: But as their Connexion proves loose, or any one of them becomes deficient, or abounds in an Over-Proportion, then the Wine is faulty,

* See *Lect. XI. Exp. IV.*

and exposed to Injuries and Alterations for the worse: And this shews us the true Foundation of what may be called the *Health* or *Diseases* of *Wines*.

28. That a large Proportion of Water necessarily enters the Composition of Wine, appears plainly by its artificial Preparation *a)*; and again from the Congelation of the natural *b)*. But though this large Quantity of Water is requisite in the Fermentation, and serves to carry it on the better; yet it is not afterwards essential to the Wine, but rather foreign and detrimental, exposing and subjecting it to Changes, which it would not otherwise undergo: Whence the sovereign Remedy for all Wines, is to deprive them of their superfluous Water, in order to render them perfect and unchangeable, without some uncommon and extraordinary Violence or Accident. And indeed this Remedy is so effectual as to make all others unnecessary; insomuch that the poorest and thinnest Wines may, by its Means, be rendered perfectly durable, and full bodied *b)*.

29. But as there may be some Difficulty in the particular Use of this grand Remedy (in the large Way of Business) the next Expedient is, to use highly rectified and pure Spirit of Wine, in such Proportion as to prevent all Change for the worse, and preserve the essential Parts of the Wine, as it were by a Balsam. But when the Case is very bad, this Remedy of itself will scarce prove sufficient, unless assisted by somewhat to give a Body as that gives Strength. Whence it is highly convenient to have always at Hand a

a) See *Lect. VII. Exp. I.*

b) See *Lect. XI. Exp. IV.*

Quantity of Wine made as rich as ever it will ferment; a suitable Proportion whereof being added along with the Spirit, will have a very good Effect; especially if the Whole be quickened with a little *essential Oil of Wine*, which, in the Case of over-aqueous Wines, is generally deficient. And this being a capital Disease in Wines, or that to which most of the rest are originally owing, it may be proper here to give a Form of a Remedy which has been found effectual for the Purpose.

30. Take an Ounce of fine *essential Oil of Wine*, mix and grind it with a Pound of dry Loaf-Sugar into an *Eleosaccharum*; dissolve this *Eleosaccharum* in two Gallons of the richest Wine; and add to it two Gallons of the finest Spirit of Wine, so as that they may be well incorporated together. The Dose of this Mixture must be proportioned to the Exigence; but in ordinary Cases one half will suffice for a Pipe of Wine.

31. There is a Disease of Wines opposite to the former, and that is when too much of their aqueous Moisture is drawn from them, whence they become dry and parched, as it were, for Want of it. This Case indeed cannot well happen, except by the Method of Condensation; whereby Wines may have their essential Parts brought so close together, as to become unfit for Drinking till set more asunder, and diluted. But this must not be attempted with Water alone, for Fear of inducing a Flatness. The best Way is, to have a dilute or thin tasteless Wine ready at Hand for the

the Purpose *a*) ; whereby any Degree of Smallness may be given at Pleasure.

32. But the artificial Method of preparing Wines renders all Remedies unnecessary, as it intirely prevents their Diseases ; so that they need not be made either too aqueous, or too dry, but constantly of a perfect full Body, and therefore not subject either to Acidity, Ropiness, or Foulness, when once well cleared of their gross Lees, in the ordinary Way of Racking.

33. But in Case the Wine should not soon grow fine of itself. the Addition of a little tartarized Spirit of Wine will hasten the Effect *b*) : Or, to make at once a general Remedy for Wines that are too poor and aqueous, or will not thoroughly fine themselves ; let a pure, tasteless, and totally inflammable Spirit be made from Sugar ; digest this Spirit upon a tenth Part of pure and dry Salt of Tartar for three Days ; decant the Liquor, and put it to ten Times its own Quantity of a Wine made as rich as it possibly would ferment : Of this Preparation six or eight Quarts will at any Time mend, improve, and fine down a Pipe of ordinary Wine.

a) See *Leç. VII. Exp. I.*

b) See *Leç. XI. Exp. II. IV.*

LECTURE XII.

CONTAINING

Attempts to illustrate and improve the Arts depending upon DISTILLATION; viz. Malt-Stilling, Rectifying, and Compounding.

The Subject.

1. **H**AVING already gone through the Arts depending immediately upon *vegetable Fermentation*, we next proceed to consider the Ways of improving the Art of *Distillation*, which depends thereupon secondarily.

Distillation, what.

2. The Word *Distillation* is here used in the popular Sense, to signify the Art by which all inflammable Spirits, Brandies, Rums, Arracks, and the like, are procured from vegetable Subjects, by the Means of a previous Fermentation, and a subsequent Treatment of the fermented Liquor by the Alembic, or Hot-Still, with its proper Worm and Refrigeratory.

The Arts therein concerned.

3. The Arts therefore at present to be considered are those of Malt-Stilling, Rectifying, and

and Compounding, with the Business of the Brandy-Merchant, the Officers of Customs and Excise so far as relates to Spirits, and of the several Dealers in Brandies, Rums, Arracks, and Cordial Waters.

4. The Experiments we shall exhibit will shew, *Design of the Experiments.*
(1.) the Method of Distilling a Spirit from a fermented Malt-Wort, commonly called *Wash*, in order to obtain *Aqua Vitæ*, or the ordinary Malt Spirit, of which many Cordial Waters are made by the Compounders, Apothecaries, and others :
(2.) Our *second* Experiment will exhibit the Method of purifying or rectifying this Spirit of the first Running, or, *Low-Wines*, as they are called, into a saleable Proof-Spirit, or what they emphatically call *Proof Goods*; that is, a certain standard Spirit, usually consisting of one half Water and the other half Alcohol : (3.) Our *third* Experiment will exhibit the Art of the rectifying Distiller, or the Method whereby the Proof Goods of the Malt-Stiller are made into a sweeter or cleaner Spirit, for the finer Uses of the Compounder and Apothecary : (4.) Our *fourth* Experiment will shew the true Method of examining Proof in Spirits, and discover the Invalidity of the common Methods of judging of the Purity, Genuineness, and Goodness of Brandies, Rums, and Arracks : And (5.) our *fifth* Experiment, will shew the Method of making Cordial or Compound Waters in Perfection.

EXPERIMENT I.

The Method of distilling Malt-Wash, or a fermented Mixture of Meal and Malt, for Spirit.

The Distillation of Wash.

5. We briskly stirred together the Malt-Wash prepared in the last Experiment of our last *Lecture*, and therewith filled two thirds of a Still, first made hot and dewy on the Inside with boiling Water, and kept the whole Stirring till it almost begun to boil; then we immediately clapped on the Head, and luted it down. There now soon ran, in a slender Stream, from the Nose of the Worm, a spirituous Liquor that was inflammable, or burnt in the Fire. We continued to work so long as the Liquor that came over would, when thrown upon the hot Still-Head, catch Flame from a lighted Candle applied to the rising Fume.

Low Wines.

6. And thus we obtained what the Malt-Stillers call a *Malt Low-Wine*; that is, a spirituous Liquor from fermented Malt and Meal, so diluted with Phlegm or Water, as that the last Runnings of it would not burn upon the Still-Head. That which comes over after the Spirit falls off from being Proof, till it will no longer burn on the Still-Head, is called by the Name of *Faints*

The Experiment extended.

7. This Experiment may be rendered general, by a slight Variation of Circumstances; that is, it may be made to serve as an Instance of all the Ways of procuring inflammable Spirits, whether Brandies, Rums, Arracks, Cyder-Spirit, or the like: For if any Wine, Beer, or fermented Liquor

Liquor from Sugar, Treacle, Roots, Fruits, &c. be treated in the same Manner, it will afford a Spirit differing only according to the Nature, or specific Taste and Odour, of the Subject.

8. But none of these Subjects will afford the least drop of inflammable Spirit without a previous Fermentation *a)*. Thus though the recent Juice of the Grape, or any other fermentable Juice, were distilled to Driness, yet no inflammable Spirit would be procured: Whence it appears that inflammable Spirit is a Thing produced by *Fermentation b)*.

9. The Cautions required to render the Experiment successful, and the Production perfect, are, (1.) That the Fermentation be well performed, and the Liquor become truly vinous, and of an acid Pungency *c)*; (2.) that it be gently distilled, by Means of a soft, well regulated, Fire; (3.) that the grosser Oil, apt to rise along with the Spirit, be kept back by a proper Strainer, or thick doubled Flannel, laid under the Nose of the Worm. If these Cautions be duly observed, the *Low Wines* will prove considerably pure and vinous. *Cautions.*

10. When all the Spirit is thus obtained there remains behind in the Still what they commonly call *Bottoms*; that is, the gross Parts of the fermented Meal and Malt mixed with Water. This gross Matter is generally used for the Feeding of Hogs; whence the Malt-Stillers *Management.*

a) See *Lect. VII. Exp. IV.*

b) See *Lect. XI. passim.*

c) See *Lect. VII. and XI.*

of *England* are commonly large Dealers in Hogs ; But in *Holland* that makes a separate Business.

11. Thus we have gone through three of the principal Branches of Malt Stilling ; viz. the Brewing, Fermenting, and first Distilling Parts ; or the Making of the Wort, the Working it in the fermenting Back, and the distilling it from the Wash *a*). There is but one Part more of this Art, viz. the Rectifying Part ; or the Way of *making up their Goods*, as they call it, to saleable Proof : And how this is performed will be seen by the following Experiment.

EXPERIMENT II.

The Method of simple Rectification, or Distilling the Low-Wines, produced by the foregoing Experiment, into Proof-Spirit for Sale.

Proof-Spirit.

12. We took the Low-Wines produced in the preceding Experiment, and distilled them over-again in *Balneo Mariæ*, or barely by the Heat of boiling Water ; and thus we obtained a purer and higher rectified Spirit than before, which being let down with fair Water to a certain Size or Standard called *Proof b*), is what the Malt-Stillers understand by Proof-Goods, or *their* rectified Malt-Spirit.

a) See *Leß. XI. Exp. VI.*

b) What this Proof is, see explained in the fourth Experiment of the present Lecture.

13. The common Malt-Stillers indeed do not thus rectify their Spirit in *Balneo Mariae*, but barely redistill their Low-Wines in a smaller Still; so that their Spirit is not so clean as that of our present Process. The Perfection therefore of the Art of Distilling from Malt seems to require a good Method of rectifying clean, as well as a careful Observance of the Cautions above laid down *a*).

14. Having thus regularly gone through the whole Art of the *Malt-Stiller*, as it is practised by the more intelligent Artists, we proceed to offer a Consideration or two for its farther Improvement.

15. The Inconveniencies of this Art regard either the Subject, or the Work. The Subject, we see, is Malt; which being of a large Bulk, in Respect of its saccharine Part, and requiring a great Proportion of Water to extract this Part, hence many large Vessels, such as Mash-Tuns, Coolers, Fermenting-Backs, Coarse-Stills, and Fine-Stills, become necessary therein; whereby the Labour also is increased, and the Price of the Commodity enhanced. This Art, therefore, being far removed from Simplicity, is consequently far removed from Perfection. Inconveniencies.

16. The Remedy here should seem to depend upon the Introduction of a new Art, subservient to the Art of the *Malt-Stiller*, and confining itself to the Boiling down of Malt-Wort to a Rob *b*), so as to supply the *Malt-Stiller* with his Subject, in the same Manner that the *Fine-Stiller* is now supplied by the Sugar-Baker Remedied.

a) See §. 9.

b) See *Lect. X. Exp. III.*

with Treacle: For thus the complex Business of the *Malt-Stiller* might be commodiously reduced to a great Degree of Simplicity.

17. By the same means the Spirit of the *Malt-Stiller* would also become much finer than at present; because the Subject would come tolerably refined to his Hands, or purged of its gross, mealy, and husky Matter, which yields a disagreeable Oil in Distillation; and is also apt to burn in the Still, and spoil the Spirit. We therefore recommend it to those who are skilled in this Branch of Distillation, to try whether a Spirit superior to that of Treacle may not be procured from the *Rob of Malt*, prudently prepared and fermented.

*Fine-still-
ing.*

18. There needs no particular Experiment to shew the business of the *Fine-Stiller*; that being no more than Working, in the Manner above explained, from a Wash made by fermenting Treacle with Yeast; though it is usual to add a considerable Proportion of Malt, and sometimes a little powdered *Jalap*, in the fermenting Back. The Malt accelerates the Fermentation, and makes the Spirit come out the cheaper; and the *Jalap* prevents the Rise of any crusty Head on the Surface of the fermenting Liquor, and so leaves a greater Opportunity for the free Access of the Air; which also shortens the Work, by turning the foamy into the more hissing Kind of Fermentation.

EXPERIMENT III.

The Art of the Rectifier; or the Method whereby the Proof-Goods of the Malt-Stiller are made into a cleaner Spirit, for the finer Uses of the Compounder and Apothecary.

19. To two Gallons of the common Proof-Spirit of the Malt-Stiller, procured after the Manner of our second Experiment, we added three Ounces of the Black Flux, or a Mixture of Tartar and Nitre calcined to Blackness *; and drew over all that would run in an uninterrupted Stream from the Nose of the Worm, by Means of the *Balneum Mariæ*. The Spirit which thus came over we made up Proof with fair Water. And the Spirit thus prepared is the common saleable *Proof Goods* of the rectifying Distiller, when he works to a Truth. Rectification of Spirits.

20. This is the Spirit we commonly meet with in Trade under the Name and Notion of *Malt-Spirit*, which is thus fitted for making the common Cordial or compound Waters; being cleared considerably of its foetid Oil and nauseous Phlegm, by Rectification. If it be desired still cleaner one of the best Methods is, to dilute the strongest Part that comes over first, with a large Proportion of fair Water, draw off the Spirit gently again by the *Balneum Mariæ*, and then make it up proof with fine soft Water. Malt Spirit.

21. But this Method will not yet give us the Spirit without some nauseous and disagreeable Flavour; nor do the Rectifiers appear acquainted with any good Method for that Purpose. Inconveniences.

* See *Let. II. Exp. II.*

They have been groping after it, but generally in the dark, for want of a proper Knowledge of the Facts and Experiments necessary in the Enquiry. Thus, for instance, they seem little apprehensive that it is the Oil of the Malt, residing in the Spirit, which occasions all their trouble; or that it is the essential Oil of the Subject which gives to Malt-Spirits, Brandies, Rums, and Arracks their particular Flavours. For if the essential Oil could be totally separated from Malt-Spirit, that Spirit might be rendered flavourless and tasteless; and then any other Flavour might, by Means of other essential Oils, be introduced into it; so that it might be made to resemble either *French Brandy*, Rum, or Arrack. And in the effecting of this, with Simplicity and Cheapness, the Perfection of the Art of Rectifying seems to consist.

Remedied. 22. For this purpose we would recommend the Way of Working from a Spirit largely diluted with Water, into Water again; for thus the essential Oil would be doubly separated at one Operation. But we have no great Hopes that any Direction of this Kind can prove serviceable to them, while they remain unacquainted with chemical Operations, and the best Contrivances for Distilling in the large Way with Elegance and Simplicity.

23. The Chemists, however, have helped them to a tolerable Expedient for covering the Imperfections of the Spirit which they cannot cleanse; viz. by the Addition of what is called *Spiritus Nitri dulcis*; a small Proportion whereof will give an agreeable Vinosity to a Hogthead of Spirit. But this Expedient is attended with an Inconvenience; for the Flavour is very apt to fly off, or be lost, when the Spirit is kept in a Cask: But the Success proves different, when the

the Spirit is kept and well stopped down in a Glass.

24. The Art of the *Rectifier* might be entirely *Improve-* set aside as useless, if the original *Malt-Stiller* *ments.* could make his Spirit perfect at a second Operation, as we judge he might. But here again the *Malt Stillers* can scarce be brought to forsake the beaten Track. If they are disposed to improve their Art, we would recommend to them, *first*, the Brewing in Perfection; and *secondly*, the Keeping of their Wash, after the Manner of stale Beer, till it has entirely lost its Malt Flavour, and acquired a pungent, acid, Vinosity; and then, *thirdly*, leaving out the Lees, to distil with a well-regulated Fire. Those who have not tried would scarce conceive what an agreeable Spirit may be thus procured from Malt, at the very first Distillation. The gainful Part of the Secret depends upon an artificial Method of making *Malt Liquors expeditiously stale, bright, and flavourless, but in other respects vinous* *.

EXPERIMENT IV.

The Method of examining Proof in Spirits; and detecting the Invalidity of the common Ways of judging of the Purity, Genuineness, and Goodness of Brandies, Rums, and Arracks.

25. We took a long Phial, half filled with *Proof* the common Proof-Spirit of the *Malt-Stiller*, *taken of* and giving it a smart Stroak with its Bottom *Spirits.* against the Palm of the Hand, there appeared on the Surface of the Liquor a Chaplet, or Crown of Bubbles, which went off, or disappeared, in a certain strong Manner; that is, it first

*) See Appendix to *Lect.* XI. See also *Lect.* VII.

remained a while, and then went off by Degrees, without breaking into smaller Bubbles, or rising into larger. And when the Bubbles go off in this Manner, the Spirit is said to be proof or merchantable *.

Erroneous.

26. And by this Kind of Proof all Distillers, Brandy-Merchants, Brokers, and the Officers of the Customs and Excise, judge of the Strength and Quality of Brandies and Spirits, in all the Brandy-Countries and Sea-Port Towns of *Europe*: whence it is also conveyed to other Parts of the World. It may therefore appear strange to oppose the general Opinion and Practice, in a particular where the Interest of so many trading People, watchful against all Imposition, is concerned: And yet we undertake to shew, that this Kind of Proof is a mere Fallacy and Deception; for if but a little vinous or saccharine Matter, as Treacle, Syrup, Must, the Rob of Fruits, &c. be added to a Quantity of highly rectified Spirit of Wine, this slight Addition will give a Brandy-Proof to that Spirit; which, therefore, by this Trial, may be made to pass for Brandy; that is, for a Composition of half Water and half Alcohol, whereas in Reality it is almost totally Alcohol.

Detection.

27. The Fraud is easily detected; not in the common Way practised upon the *Keys*, but by burning a little of the Spirit in a Spoon; for thus it will leave the saccharine Matter behind in a dry Form.

Sophistication.

28. Whether there be any Method commonly known in *Europe*, of making a spirituous Liquor that contains much less than a half of Alcohol, to pass current for Proof-Spirit, is not so certain: But doubtless this might be

* See *Lit. VII. Exp. IV. § 36, 37.*

might be easily effected; for we see that Arrack is Proof, or affords a strong Crown of Bubbles, upon shaking, as well as Brandy; yet Arrack contains not usually above half the Quantity of Alcohol that Brandy does; and if but a Drop or two of its own or any other essential Oil be added to a Pint of Proof-Brandy, this is sufficient to destroy its Proof, and make it appear much weaker than it is.

30. To prevent being imposed upon in this *Discovery*. Way, we might have Recourse to the *Essay-Instrument*, or *Hydrostatical Balance*. A Gallon of Alcohol is computed to weigh seven Pounds and a half, and a Gallon of Water, eight Pounds; whence the compound Gravity of an equal Mixture of the two may be assigned. But it is a more sure and ready Method, to burn a little measured Quantity of the Brandy to be tried, in a cylindrical metalline Vessel, plunged in cold Water to an equal Height with the Brandy, and when it ceases to burn, exactly measuring the Remainder, which is the Water: Where if the Spirit has lost one half of its Measure by Burning, the Brandy may be allowed Proof; if more or less, it must be judged of accordingly*.

31. But besides the false Method of judging of *Essay Li-* the Strength of Brandies by what is called Proof, *quors.* there is another no less fallacious one of judging of their Genuineness; tho' kept a great Secret in few Hands, as a Thing some Dealers imagine a certain Criterion for determining whether foreign Brandies are mixed with Corn Spirits. These Dealers are provided with a certain *yel. li. Ust.* low Liquor, a few Drops whereof being poured

* See a Paper by M. Geoffroy, to this Purpose, in the *French Memoirs*.

into a Glass of right *French* Brandy, gives it a beautiful blue Colour; by the Strength and Brightness of which Colour they judge of the Genuineness, or unmixed State of the Commodity, and buy upon this Kind of Proof: Whence they may come to be much deceived; for if an ordinary Malt Spirit was to be coloured with Oak, it would sustain the present Method of Proof, and might therefore be purchased by these Dealers for *French* Brandy.

*How
made.*

32. This Proof-Tincture, or *Essay Liquor*, may be expeditiously prepared, by dissolving a little green Vitriol (first calcined to Redness) in a weak Spirit of Sea-Salt; which thus becomes a *yellow Liquor*, a single Drop or two whereof being added to a Glass of any inflammable Spirit coloured yellow or brown with Oak, will instantly turn it of a beautiful bright Blue: Whence it is evident that this Kind of Trial is no more than a Fallacy, and only shews when Brandies are tinged with Oak, as they constantly are by lying long in the Cask. And that it is the Oak which thus causes *French* Brandies to turn blue with the *Essay Liquor*, appears again from hence; That if the best and oldest *French* Brandy be re-distilled, and thus made colourless, it will not turn blue with the *Essay Liquor*; because all the Tincture of the Oak, or tinging Matter of the Cask, is left behind in the Still.

*Its Fallacy
detected.*

33. One of the best Methods to prevent being imposed upon by the Mixing of Malt-Spirit with a finer, is to acquire a Habit of judging by the Taste and Smell; for Malt-Spirit is usually so ill rectified, by the Addition of fixed alkaline Salts, or certain flavouring Ingredients, that it may easily be perceived by the Nose or Palate; especially if the Brandy proposed for Examination be largely diluted with Water, to prevent

prevent its over-heating the Mouth ; or else be burnt in a Spoon, so as to leave the Phlegm to be tasted and smelt by itself : For this Phlegm, if the Brandy were debased by a Corn Spirit, will taste and smell exceedingly nauseous, very different from the Phlegm of pure *French Brandy*.

EXPERIMENT V.

The best Method of making Cordial or Compound Waters.

54. We infused a Pound of fresh Citron-Peel in two Gallons of good Melasses Spirit, and committing the whole to the Still, drew off the Spirit gently, with Care to avoid the *Faints*; then *making up*, as they call it, with soft Water, so as to leave the Liquor Proof, we added half a Pound of fine Sugar, and thus procured a genuine *Citron Water*. *Citron Water prepared.*

35. This Experiment is general, and shews the usual Methods of making all the Compound or Cordial Waters, by those Distillers who are called Compounders, and also by Apothecaries; tho' Apothecaries seldom make distilled Waters so good as the Compounders. *The Experiment extended.*

36. The Perfection of this Branch of Distillation depends upon the Observance of a few Rules, which might be easily complied with: And these Rules we shall here lay down, as judging them of Consequence to the Improvement not only of the Art of the Compounder, but also of a Branch of Pharmacy and Medicine. *Compound Distillation improved.*

37. The first Rule is, *To use a well-cleansed Spirit, that is freed from its own essential Oil.* For as the Design of compound Distillation is to impregnate the Spirit employed with the essential Oil. *Rules.*

Oil of the Ingredients, it ought first to have deposited its own.

38. The second Rule is, *To suit the Time of previous Digestion to the Tenacity of the Ingredients, or the Ponderosity of their Oil.* Thus Rhodium-Wood and Cinnamon require to be longer digested before they are distilled than *Calamus Aromaticus*, or Lemon Peel. Sometimes also *Cohobation* (that is, the pouring of the Spirit once drawn off, back upon the same Ingredients) proves necessary; as particularly in making the strong Cinnamon Water, where the essential Oil is extremely ponderous, and hardly rises along with the Spirit, without one Cohobation more.

39. The third Rule is, *To suit the Fire or Strength of the Distillation to the Ponderosity of the Oil intended to be raised with the Spirit.* Thus strong Cinnamon Water should be distilled off brisker than the Spirit of Mint or Baulm.

40. The fourth Rule is, *That a due Proportion of only the finer essential Oil of the Ingredients be thoroughly united or incorporated with the Spirit, so as to keep out the grosser and less fragrant Oil.* And this may be chiefly effected by leaving out the *Faints*, and making up to strong Proof with fine soft Water in their Stead. And upon the Observance of these four easy Rules the Perfection of the Art of compound Distillation seems to depend.

41. The Addition of fine Sugar to Cordial Waters is a Thing of less Moment, and may be used or omitted occasionally. And if these Directions be observed, there will be no need of fining down Cordial Waters with Allum, Whites of Eggs, Ising-Glass, or the like; for they will be presently bright, sweet, and pleasantly tasted, without any farther Trouble.

42. And

42. And thus we hope to have shewn the Way of perfecting the Art of compound Distillation, even by the common Alembic, or hot Still, without the Use of the *Balneum Marie*; for which there is here no Occasion, if the Artist be but expert in working by the Alembic.

AXIOMS and CANONS.

1. We learn from our present Enquiry, that inflammable Spirits are the Creatures of vinous Fermentation; or that they are actually produced, tho' not-separated, in that Operation *a*).

2. That the Action of Fermentation produces such a Change in the Wash, as to render it separable by the Fire into several Portions of Matter, besides the inflammable Spirit, specifically different from what the Liquor would have afforded by the same Treatment before Fermentation *b*).

3. That at different Times of Distillation there come over Liquors of different Properties; and first of all, an extremely acrid, aromatic, and biting one; which goes off by Degrees, and ends in Acidity *c*).

4. That the Art of *Malt-Stillling* may be considerably improved; (1.) by reducing the brewing and fermenting Parts to one Operation; (2.) by distilling slow; and (3.) by keeping back the gross Oil of the Subject.

5. That this Art may be farther improved, by fermenting a clear, well-brewed Wort, and keeping it to be stale, or till it has lost all Fla-

a) See Exp. I.

b) See Lect. VII. Exp. IV. See also Appendix to Lect. XI.

c) See Exp. I. and Appendix to Lect. XI.

your of the Malt; as it will naturally do by long lying, or in a very short Time by the Help of a certain artificial Treatment *a*).

6. That the Perfection of the Art of *Malt-Stilling* requires the Assistance of a new Art, to produce a Kind of Treacle from Malt, or the Reduction of the Art of the *Malt-Stiller* to the same Simplicity as that of the Fine Stiller *a*).

7. That the essential Oil of the vegetable Subject is the Thing which gives to all Spirits their particular Odours and Flavours *b*).

8. That the finest, most subtil and efficacious Part of this essential Oil always rises first in Distillation *b*).

9. That the Purity and Perfection of Spirits, considered merely as Spirits, greatly depend upon their being cleansed first of the essential Oil, especially its grosser Part, and next of the Phlegm *c*).

20. That Brandies are a Mixture of one half Water, and the other half Alcohol; that the Measure of the Strength of Brandies is the Quantity of Alcohol they contain; and therefore that their Water may be commodiously left behind upon Exportation or Carriage *d*).

11. That as Brandies hold some small Proportion of essential Oil, they are in Strictness dilute *Quintessences c*); whence their Properties and Effects may be easily explained, in a chemical Manner.

a) See *Exp. I. and III.*

b) See *Exp. I. III. V.*

c) See *Exp. I, II, III. V.*

d) See *Exp. I, II, III, IV.*

12. That

12. That the Perfection of Rectifying Spirits depends upon finding out a simple Method of separating all the Oil and Water from a Spirit *a*).

13. That the great Affinity betwixt the essential Oil and Spirit is the physical Cause of the Difficulty found in the Rectification of Brandies *b*).

14. That the Perfection of the Art of *Malt-Stillling*, whereby a pure Spirit might be procured at the first Operation, would supersede the Art of Rectifying *a*).

15. That the Bubble Brandy-Proof may be artificially given to high rectified Spirit of Wine, and easily destroyed in Proof-Spirit, without weakening the Spirit *c*).

16. That the common Methods of trying and examining Brandies by the Bubble-Proof, and by their turning blue with a vitriolic Solution, are absolutely fallacious, and not to be trusted for the Purposes intended *d*).

17. That *physical Proof* in Brandies is the Property they have, upon shaking, to generate a Crown of moderately large Bubbles on their Surface, by Means of a certain Tenacity, arising from a stated Proportion of essential Oil dissolved in among them; which Tenacity may also be given by other Bodies *d*).

18. That a sure Method of determining the Strength of Brandies is by Deflagration, or burning away their Alcohol; then examining the remaining Phlegm by Weight or Measure, and

a) See *Exp. I* & *II*.

b) *Exp. I, II, III, V*.

c) *Exp. III, IV*.

d) *Exp. IV*.

comparing it with the Weight or Measure of the Alcohol *a*).

19. That erroneous Notions, or inaccurate and false Methods of Trial, may prevail, and become almost universal in Trade; so that even the prudent Merchant shall buy and sell upon weak Trials, whilst the Detection, Rectification, or Adjustment thereof, belongs to some other Branch of Knowledge *a*).

20. That the Way of perfecting the Art of compound Distillation is, (1) To procure a well-cleansed Spirit; (2) To use proper Digestion; (3) To distil brisk, or slow, as the Subject requires; and (4) To keep back the Faints, and the gross Part of the essential Oil of the Ingredients *b*).

a) *Exp. IV.*

b) *Exp. V.*

LECTURE XIII.

CONTAINING

The Ways of procuring Vegetable Oils and Salts ; with their Uses in several Arts and Trades.

I.

1. **W**E now proceed to illustrate and improve the common Methods of procuring and employing vegetable Oils and Salts ; on which the Exercise of various Arts and Trades depends.

2. The Parts of Vegetables that chiefly abound with Oil are, the Seed, the Leaves, the Fruit, and the Bark. Thus the Seeds of Mustard, and of the Sun-Flower, Almonds, Nuts, Beech-Mast, &c. afford a copious Oil by Expression ; and the Leaves of Rosemary, Mint, Rue, Wormwood, Thyme, Sage, &c. the Berries of Juniper, Olives, Indian Cloves, Nutmeg, Mace, &c. the Bark of Cinnamon, Sassafras, &c. yield a considerable Proportion of essential Oil by Distillation *.

3. And much in the same Manner is Oil or Fat contained in the Parts of Animals ; being either interspersed among the muscular Flesh, collected into particular Bags or Cells, or lodged in the Cavities of the Bones, &c.

* See below, Exp. II.

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*The Design
of the Ex-
periments.*

4. Our *first* Experiment will shew the Method of procuring Oils by Expression, from Nuts, Seeds, Mast, Olives, &c. The *second* Experiment will exhibit the Method of procuring those called the Essential Oils of Vegetables. The *third* Experiment will shew the Method of rectifying those called the Empyreumatic Oils. Our *fourth* Experiment will shew the Method of refining Sugar. The *fifth* Experiment will shew the Way of refining *Tartar* : Our *sixth* the Manner of refining *Nitre*, or Salt-Petre ; and our *seventh* will shew the Method of making Pot-Ash.

EXPERIMENT I.

The Method of procuring Oil by Expression, from Nuts, Seeds, Mast, &c.

*Expressed
Oil of Al-
monds.*

5. We took two Pounds of Sweet Almonds, blanched, and beat them small in a Stone Mortar ; then wrapping the Mass up in a Piece of strong and thick Canvas, we committed it to a strong Screw-Press ; where being squeezed betwixt two cold Iron Cheeks, it gradually parted with a considerable Quantity of Oil.

*The Expe-
riment ex-
tended.*

6. This Experiment holds of all those vegetable Matters that contain a copious Oil, in a loose Manner, or in certain Cavities or Receptacles ; the Sides whereof being burst by squeezing, makes them let go the Oil they contain. And thus the Zest, or Oil of Lemon-Peel, Orange Peel, Citron-Peel, &c. may be readily obtained by Pressure, without the Use of Fire ; for the Rinds of those Fruits being pressed green, the oily Parts will separate from the aqueous,

aqueous, and may be rendered pure by washing them in fair Water *.

7. How far this Method of obtaining Oils may be applied to Advantage, seems not hitherto considered. It has been commonly applied to Olives, Almonds, Lint-feed, Rape-feed, Beech-Mast, Ben-Nuts, Wallnuts, Bay-Berries, Mace, Nutmeg, &c. but not that we know of to Juniper-Berries, Cachou-Nuts, *Indian* Cloves, Pine-Apples, or Fir-Nuts, and many other Subjects that might be enumerated, both of foreign and domestic Growth. It has however been of late applied to Mustard-feed, with good Success; so as to extract a curious yellow, or golden-coloured Oil from that Seed, and at the same Time leave a Cake behind fit for making the common Table Mustard.

8. Certain dry Matters may, as well as moist ones, be made to afford Oils by Expression; for when they are not so moist as Almonds, or fit to be reduced to a Pulp in a Stone Mortar, they may be ground into a Meal, which, being suspended to receive the Vapour of boiling Water, will thus be moistened so as to afford an Oil, in the same Manner as Almonds; especially if the Iron Cheeks employed be first heated, by lying in boiling Water. And thus an Oil may be procured from Lint-feed, Hemp-feed, Lettuce-feed, White Poppy-feed, &c.

9. The Oils obtained by this Treatment, *Regulated.* should be suffered to depurate themselves by standing in a moderately cool Place, to separate from their Water, and deposite their Fæces; from both which they ought to be carefully freed. And if in this Manner they are not

* See below, § 9.

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rendered sufficiently pure, they may be well washed and beat with fresh Water, and then thoroughly separated from it again, by the Separating-Glass; by which Means they will be rendered bright and clean.

10. Particular Care must be taken to keep such of these Oils cool as are designed for eating, or for any internal Use; because they are apt in a few Days Time to turn rancid and corrosive with the Summer's Heat, so as to prove very unwholesome. Hence the Physician and Apothecary should be cautious that the Oils given in Pleurifies, and other Distempers, be fresh drawn from sound Subjects, no way tainted, or already turned rancid, as Almonds, Pistachios, and other Nuts, are apt to be: And again, that these Oils have felt no considerable Heat, either in the Drawing, or by standing long in a warm Place. And the same Caution should likewise extend to animal Oils and Fats, intended either for internal or external Use; since these also become rancid, or change to a yellow, red, or grey Colour in hot Weather, and thus become exceedingly nauseous and corrosive; as we see in Butter, Bacon, and other fat Bodies, which then prove fit only for the Tallow-Chandler, or other ignoble Uses.

*Applied to
other Sub-
jects.*

11. Our present Experiment is likewise applicable to the procuring of Oils or Fats from certain animal Subjects; for the Membranes, the skinny, and stringy Parts of animal Bodies, which contain much Fat, being chopped small, and set in a Pan over the Fire, become fit for the Canvas-Bag, and by Pressure afford a large Quantity thereof; as we see in the Art of Chandlery, which thus extracts the oily Matter, leaving

leaving behind a hard Cake, or what they commonly call *Graves*.

12. These *Graves*, and all the Residuums of the present Process, after being squeezed ever so hard with the Press, will still afford a copious Oil by boiling in Water; so that it might perhaps be more profitable for the *Tallow Chandler* to boil his *Graves* for Oil, as Bones are usually boiled for it, than to dispose of them in the ordinary Manner. And it is surprizing to observe, what a large Proportion of Oil these dry, and to appearance almost exhausted Bodies, will yield, by repeated boiling in Water, but particularly by being committed to the *Digestor* *.

13. So likewise if the Almonds remaining in the Canvas, after the Expression of their Oil, be ground in a Mortar with warm Water, the Water will thus extract their remaining Oil, and turn therewith into a milky Liquor, or *Emulsion*. And if this Operation had been performed upon the Almonds at first, before we committed them to the Press, we might thus have got out all their Oil, and left only a dry, chaffy, or light, husky, and exhausted Matter behind. Whence we have a Method of dissolving Oils in Water, and thereby of making a Kind of artificial Milk; which, by standing, will afford a Cream, and turn sour, like the Milk of Animals, but not grow rancid with Heat, like Oil. Whence such Emulsions may, in some Cases, be medicinally used with greater Safety and Success than expressed Oils. *Farther Uses.*

14. Any of these expressed Oils will receive particular Colours and Odours at the Discretion of the Artist. For Example: If a little *Oils coloured.*

* See *Let. VI. Exp. VII.*

Alkanet-Root be barely infused in Oil-Olive, it gives a beautiful red Colour to that Oil, without altering its Taste. So again; if a few Drops of the essential Oil of Cinnamon be added to a Pint of Sallad Oil, such Sallad Oil may be rendered thereby agreeable to those who admire the Flavour of Cinnamon. And thus may Oil, Butter, &c. be diversified infinite Ways, by a proper Use of tinging Ingredients, and suitable chemical Oils.

Essences.

15. The same Contrivance has likewise its Uses in making Essences for the Service of the *Perfumer*; not only where essential Oils are procurable, but also where these either cannot well be obtained, or but in small Quantity. The essential Oil of Jasmin Flowers, Honey-Suckles, Sweet Briar, Damask Roses, Lilies of the Valley, &c. are either extremely dear, or scarcely obtainable by Distillation; and in some of them the odorous Matter is so subtil as to be almost lost in the Operation. But if Jasmin Flowers, Damask Roses, Lilies of the Valley, &c. be barely infused in fine Oil of Nuts, or Oil of Ben, drawn without Heat, and kept in a cool Place, the subtil odorous Matter of the Flowers will thus pass into the Oil, and richly impregnate it with their native odoriferous Spirit; which can scarce otherwise be procured, or separated from the Flowers, without Loss, or Debasement. And these Essences may be rendered perfect by straining off the Oil at first put on, letting it stand again, without Heat, upon fresh Flowers, and repeating the Operation twice or thrice.

What they are.

16. If we consider the Thing attentively, we shall find that the Essences thus obtained are a Kind of *essential Oils*, not greatly differing from those prepared by Distillation from the Flowers, Seeds,

Seeds, or Barks of odoriferous Vegetables; for all such *essential Oils* are found to be little more than the native odorous Spirits of the vegetable Subject, wrapped up, lodged, or entangled in an unctuous or direct oily Substance. This oily Substance indeed rises, or becomes volatile, by the Heat of boiling Water; but so do not the Oils gained by Expression*: Whence the principal Difference betwixt those *natural*, and *artificial essential Oils*, as we may call them, seems to consist in the different Tenacity, Volatility, or Fixedness of their unctuous or direct oily Parts, the *native Spirit* appearing the same in both; tho' indeed it is more delicate and unimpaired in the artificial Kind of essential Oils, as not having felt the Force of Fire. And hence perhaps some considerable Improvements might be made in the Art of the *Oilman*, *Perfumer*, and *Apothecary*; not to mention other œconomical Uses, and the Art of the *Dairy*.

EXPERIMENT II.

The Method of procuring the essential Oils of Vegetables by Distillation with Water.

17. We took eight Pounds of Juniper Ber-
ries, and bruising them in a Stone Mortar, directly put them into a Still, together with four Gallons of River-Water; then working with a brisk Fire, we drew off a Gallon of Water, and obtained along with it a considerable Proportion of a fragrant essential Oil, which we

*Essential
Oil of Ju-
niper di-
stilled.*

* See *Exp. II.* hereafter.

sepa-

separated from the Water by a Separating-Glass.

The Experiment extended.

18. This Experiment is easily rendered general, or made applicable to the Distilling of the essential Oils from Flowers, Leaves, Barks, Roots, Woods, Gums, and Balsams, with a slight Alteration of Circumstances; as by longer Digestion, brisker Distillation, &c. according to the Tenacity and Hardness of the Subject, the Ponderosity of its Oil, &c. a).

Uses.

19. If the Liquor that remains in the Still, after the present Operation, be strained, and evaporated to the Consistence of Honey, it makes the *Rob of Juniper-Berries*, which may perhaps defray the Charge of the Operation, it being esteemed a valuable Medicine, and used as a Strengthenener of the Stomach and Intestines, as a Preservative from the Stone and Dropsy, and as a Cure for the Disorders of the urinary Passages.

Essential Oils classified.

20. Essential Oils may be divided into two Classes, according to their different specific Gravities; some floating upon Water, and others readily sinking to the Bottom thereof. Thus the essential Oils of Cloves, Cinnamon, and Sassafras readily sink; but the Oils of Lavender, Marjoram, Mint, &c. swim in Water. The lightest of these essential Oils is, perhaps, the Oil of Citron-Peel, which floats even on Spirit of Wine; and the heaviest seems to be the Oil of Sassafras: But the specific Gravities of the intermediate essential Oils are not hitherto adjusted and *tabled*, as for the Service of Chemistry they ought to be b).

a) See *Let. XII. Exp. V.*

b) See below, §. 29.

21. For obtaining the full Quantity of the more ponderous Oils from Cinnamon, Cloves, Sassafras, &c. it is proper (1) to reduce the Subjects to fine Powder; (2) to digest this Powder for some Days in a warm Place, with thrice its Quantity of soft River Water, made very saline by the Addition of Sea-Salt, or sharp with Oil of Vitriol; (3) to use the strained Decoction, or Liquor left behind in the Still, instead of common Water, for a fresh Digestion; (4) to use for the same Purpose the Water of the second Running, after being cleared of its Oil; (5) not to distil too large a Quantity of these Subjects at once; (6) to leave a considerable Part of the Still, or about one fourth, empty; (7) to use a brisk Fire, or a strong boiling Heat, at the first, but to slacken it a little afterwards; (8) to have a low Still-Head, with a proper internal Ledge and Current leading to the Nose of the Worm; and (9) to cohobate the Water, or pour back the Liquor of the second Running upon the Matter in the Still, repeating this once or twice.

How obtained to Advantage.

22. These Cautions are all necessary, in order to distil the ponderous essential Oils to Profit and Perfection. The physical Reasons whereon they depend may deserve to be considered. (1) The Reduction of the Subject to Powder, exposes all its Parts the better to the Action of the Water and Salt; whereby the Oil is the more mollified, attenuated, and rendered fitter to rise along with the aqueous Vapour in Distillation. (2) The Digestion is requisite for the same Reason; as being no more than allowing Time for this Action to be performed, in a moderate Warmth. The Water should rather be the soft Water of Rivers, than that of Rain, which is more corruptive or fermentative; or than

Reasons of the Caution.

than that of Springs, which is often hard, so as not to mollify the Oil, but rather defend it from the Action of the Salt, or Acid; which are added not only to prevent all Tendency to Fermentation or Corruption, that would absolutely change or destroy the Oil, but more particularly, as having a known Property of attenuating, liquifying, dissolving, and purifying gross, viscous, and tenacious Oils. Besides which, it likewise increases the specific Gravity of the Water; whereby the Subject is now buoyed up, so that it cannot readily touch the Bottom of the Still, or come in the way of the Fire to be scorched. At the same Time this Addition also increases the Heat of the Liquor, or makes it exceed that of mere boiling Water; whence the Ascent of the Oil is likewise promoted. (3) The strained Decoction is properly used instead of Water, as being already saturated with oily Particles, so that it cannot much rob the Subject. And (4) the same holds also of the Water of the second Running, which necessarily contains some oily Particles. (5) If too large a Quantity of the Subject be distilled at once, the Heat will necessarily act unequally, or be strong upon some Parts, and weak upon others; whence, as the Oil is so extremely ponderous, a large Part of it will be left behind in the Subject. (6) If too much empty Space be left in the Still, it will be difficult for the ponderous Oil to ascend; and if too intense a Heat be used, it destroys the grateful Odour of the Oil, without raising any considerable Quantity; and if the Still be filled too full, the Matter will be apt to boil over, and foul the Oil. (7) The Fire is ordered to be brisk at first, to prevent the Oil, now in some Measure separated by the Heat, from going back into the Subject;
But

But after a Part is thus come over, if the Fire be not a little slackened, the Oil is apt to scorch, and come out at the Nose of the Worm in the Form of a Smoke, that cannot be caught and condensed; yet the whole Operation need not be continued long, or above two Hours, because the valuable Part of the Oil soon comes over.

(8.) If the Head of the Still be not low, the ponderous Oil will have too far to rise; and unless the Oil be directed to the Worm by a proper Ledge and Current, a considerable Part will fall back into the Still, and so prolong the Operation, or lessen the Yield. (9.) Lastly, two or three Cohobations, or Returns of the Water upon the Subject in the Still, must needs bring over all the Oil that will any way rise. And Water already somewhat impregnated with the Oil, is manifestly better for the Purpose than such as has never been used before.

23. The Directions here laid down, for obtaining the ponderous essential Oils to Advantage, are easily transferred to the obtaining of the lighter: So that we need not dwell particularly upon them.

24. Many of these *essential Oils* being costly *Essential* things, it is common to adulterate or debase *Oils adul-* them several Ways, so as to render them cheaper *terated.* both to the Seller and Buyer. These several Ways seem reducible to three general Kinds, each whereof has its Method of Detection; for as in *Logic* every Sophism has its Redargution, so in *Chemistry* every Fallacy may be discovered.

25. Essential Oils are adulterated, (1.) with expressed Oils, (2.) with Alcohol, and (3.) with cheaper essential Oils.

26. (1.) If any essential Oil be adulterated *The Fraud* with an expressed Oil, this is easily discovered, *discover-* by adding a little Alcohol to a few Drops of the *able.* suspected

suspected essential Oil, and shaking them together: For the Alcohol will thus dissolve all the Oil that is truly essential, or gained by Distillation, but leave the expressed Oil untouched; whereby the Compound of the two will be separated, so as that their Quantities may be judged of, or the Proportion of the Debasement found: And then by adding Water to the Alcohol, which had taken up the essential Oil, the Water will unite with the Alcohol, and leave the essential Oil separable in its own Form.

27. (2.) If an essential Oil be adulterated with Alcohol, as it may be in any Proportion up to that of an equal Quantity, without being easily discoverable either by the Smell or Taste: the Way of Detection is, to let a few Drops of the suspected Oil fall into a Glass of fair Water; for if Alcohol be mixed with the Oil, the Water will immediately turn milky, which it would not do if the Oil were pure. And by continuing to shake the Glass, the whole Quantity of Alcohol employed in the Adulteration will unite with the Water, and leave the Oil undissolved behind.

28. (3.) The third Method above mentioned, of adulterating the richer chemical Oils, is by mixing them with the cheaper essential Kinds; such in particular as the Oil of Pine-Wood, Oil of Turpentine, &c. And this is frequently practised, by putting Fir-Wood, Turpentine, or Oil of Turpentine, into the Still, along with the Herbs, suppose Rosemary, Lavender, Origanum, &c. in the same Manner as Distillers add common Malt Spirit in the Distilling of Wine Lees. And by this Means the Yield of an Oil may be considerably increased. But the Oils thus adulterated will discover themselves in Time, by the want of their natural Flavour, which

which is overpowered by that of the Turpentine, &c. But the quicker Detection is, to drench a Piece of Paper, or a Linen Rag, in the suspected Oil, and hold the Paper or Rag before a gentle Fire; for thus the grateful Odour of the Plant will soon fly off, and leave only the Smell of the Turpentine, &c.

29. But if this Way of adulterating essential Oils be practised in Perfection, it seems scarce discoverable, unless the *Table of the specific Gravities of essential Oils*, above recommended *, were ready at Hand. For it is known to some few that *Balsam Capiwi* yields a large Proportion of essential Oil by Distillation with Water, even to the quantity of five or six Ounces from a Pound; and that this Oil is much sweeter than any of those before said to be used for Adulteration: Whence it is easy by distilling any of the aromatic Vegetables along with this Balsam, or by mixing their Oils with the Oil of *Balsam Capiwi*, to debase them largely, without being greatly subject to Discovery, except by the more philosophical Chemists, who understand the uses of the *Hydrostatical Balance*. But it should be observed whether, by long keeping, the chemical Oils thus adulterated with the Oil of *Balsam Capiwi*, will not discharge the Ink of the written Label, fastened to the containing Glass, as essential Oils adulterated with Oil of Turpentine, or other terebinthinaceous Oils, are found to do, on account of the acid Vapour that continually exhales from such adulterated Oils.

30. The Methods already laid down for detecting the Sophistifications commonly practised in *essential Oils*, are general; besides which

* See §. 20.

some Oils require peculiar Methods. Thus the essential Oil of Camomile Flowers may be certainly known to be adulterated with Copper and Oil of Turpentine, &c. if it retains its original blue Colour above a Year. The essential Oil of Rue, if genuine, remains fluid in the Cold, and if adulterated, congeals. And every Fact of this Kind, of which there are many already known, should be duly collected: For it is certainly of great Importance to Medicine, that the genuine essential Oils of Vegetables should be well distinguished from the adulterated, because capable of producing extremely different Effects in the Body; a Consequence little regarded by the fraudulent Adulterator.

EXPERIMENT III.

A Method of rectifying Empyreumatic Oils.

*Empyreumatic Oil
sweetned.*

31. It was observable in our dry Distillations of Wood *a*), Wormwood *b*), and Bone *c*), &c. that there always came over a gross, fetid, empyreumatic Oil, of a nauseous Smell, disagreeable Colour, and abominable Taste. To rectify this Oil, we took two Pounds thereof, and washed it well by the repeated Affusion of hot Water, and stirring them well together, till at length the Water came away considerably pure; whereby the Oil was rendered less nauseous both to the Smell and Taste: Then setting it in an open Vessel over the Fire, that it might discharge the Water lodged therein by the Washing, we afterwards put it into a Glass Retort, and drew it over in a Sand Heat; whereby it left behind a black,

a) See *Leß. II. Exp. III.*

b) See *Leß. VIII. Exp. II.*

c) See *Leß. VIII. Exp. I.*

feculent,

feculent, or burnt crusty Matter, and became more fluid, sweet, and mild.

32. If the Distillation be repeated ten or twelve times, either in a fresh Retort every time, or in the same, the Oil being constantly returned upon its own *Fæces*, or *Caput mortuum*; these *Fæces* will every time increase in Quantity, so as to leave the Oil purer and thinner, till at length it becomes almost as thin and fluid as Oil of Turpentine, or Spirit of Wine; being extremely volatile, transparent, and penetrating, but still of a hot, pungent Taste, and a somewhat faint and disagreeable Odour.

The Experiment carried farther.

33. This Oil, obtained from an animal Subject, particularly from Blood, has been lately used in *England*, as a Remedy for the Epilepsy, Gout, and other obstinate Diseases, under the Name of *Oleum animale*. It was many Years since used for the same Purposes in *Germany* *. Yet doubtless it should not be given too freely as an Internal: But, as an external Medicine, it may be of Service in resolving hard Tumours, removing fixed Pains, &c. for it is extremely penetrating and discutient. And on this Account it might, perhaps, be used to Advantage in several Arts that require a highly subtilized Oil.

Uses.

34. But it being chargeable to bring the gross empyreumatic Oils to this Degree of Purity and Subtilty, many chemical Operators continue to throw them away as useless; and the rather, because of that intolerably nauseous Smell and Taste with which they affect all Things that they touch, or come in the Way of. But as large Quantities of these Oils are necessarily obtained in the Distillation of Harts-Horn, Blood, &c.

* See *Hoffman. Observat. Physico. Chym.* p. 58. 59.

it may be worth trying, whether they cannot be purified in a cheaper Manner than that above described: For Example; By drawing them over from Pot-Ash; or, what is still more profitable, by digesting them therewith, so as at length to turn the Mixture, by Sublimation, into a volatile, alkaline Salt, as good as that of Harts-Horn, Blood, putrefied Urine, &c.

And thus much for the Subject of vegetable Oils. We next proceed to vegetable Salts.

II.

EXPERIMENT IV.

The Method of refining Sugar; or bringing the sweet Juice of the Sugar-Cane into a white, dry, and solid Substance.

Sugar refined.

35. We took six Pounds of coarse or black Sugar, as it comes unrefined from the Sugar-Colonies, and dissolving it, over the Fire, in an equal Quantity of strong Lime-Water, we added the Whites of four Eggs, whisked up into a Froth, and stirred the Whole well together, in order to clarify the Sugar, after the same Manner as Syrups are usually clarified; we then boiled the Liquor to a higher Consistence than that of a Syrup, or till it would shoot grainy in the Cold. To make it do this the better, we continued to add Lime-Water at several times in the boiling. Having obtained this Point of Consistence, by the Sugar-Refiners called *Proof*, we poured the whole into a Sugar-Baker's Earthen Mould, stopping the Hole in the lower End, and setting the Mould in a moderately warm Place, the Sugar, after some Days, *set* hard, or hardened; then opening the lower Orifice

Orifice of the Mould, we inverted the sharp End into a little Pot, or *Sugar-Baker's Receiver*, and applied to the wider End, or on the Top of the Sugar, a Mixture of Tobacco-Pipe Clay and Water, made into a Kind of thin Paste, or pappy Substance. And thus the Water quitting the Clay, soaked through the Sugar, without dissolving the grained Part, and carried down with it only the treacly Matter, lodged betwixt the Pores of the Sugar; which treacly Matter was caught by the Receiver underneath. And thus, by keeping the Clay frequently wetting, and sometimes renewing it, all the Treacle was got out, and a pure Loaf of White Sugar left behind; which we afterwards dried in a warm Chamber, and kept it in a dry place.

36. The chemical History of Sugar deserves *The Pro-* to be traced through all its Stages. The ripe *cesses and* Sugar Canes are ground down in a Mill betwixt *Rationale.* Iron Rollers, kept continually feeding; so that the expressed Juice runs in a constant Stream, into its proper Receiver, from whence it is soon committed to the first boiling Pan, to prevent its turning eager: there it is boiled, scummed, and cleared of its grosser and lighter Feculencies that float a-top, and also drawn from its heavier *Feces* which fall to the Bottom. And thus the Juice is brought to a Kind of *Mellago*, or *Rob**: For the Juice of the Sugar-Cane, when first boiled down, is like the *Rob* of Malt, Raisins, the boiled Juice of the Birch or Sycamore-Tree, &c. and would never appear in the saline Form of Sugar, without some Contrivance to separate its herbaceous, feculent Part, and a particular Addition to give it a consistent Form. Both these Ends are answered by the Addition

* See *Let. X. Exp. III.*

of Lime-Water: For the Rob of the Sugar-Cane being of an acid and unctuous Nature, the Quicklime destroys the prevalent Acidity, dissolves and separates the grosser unctuous Matter, and at the same time, combining along with the truly saccharine Part, gives a solid and dry Consistence. And something of this Effect Lime-Water has in every fresh Boiling; so that by a prudent Use hereof the Sugar may, after repeated Operations, or by boiling it over again with more or stronger Lime-Water, be brought almost to a crystalline Form. And on the Strength, Goodness, and Quantity of the fine Part of the Lime, thus introduced into Sugar, depends the Hardness, Whiteness, and shining, rocky Resplendency of Loaf-Sugar. So that the Perfection of the Refiner's Art depends in a great Measure upon the prudent Choice of his Lime, and the Management of his Lime-Water.

37. The treacly Matter separated from the Sugar, is collected together and boiled, scummed, and treated with Lime-Water again, to obtain from it all the Sugar that it will afford in a dry form. When no more can be procured from it by the Sugar-Baker, it is then called *Treacle*; being before usually termed *Syrup*, which it perfectly resembles: Insomuch that a thorough Knowledge of the Art of preparing *Syrups*, with the Effects of their Different Consistences, and their Disposition to ferment, turn acid, or candy, and the best Ways of clarifying them, &c. may contribute to improve the Art of Sugars; and accordingly it appears, that most of the Improvements in the Refining of Sugars have been owing to Apothecaries and Chemists.

38. Sugar,

38. Sugar, thus refined, and discharged of its superfluous oily Parts, is thereby rendered dry, thirsty, or apt to imbibe aqueous Moisture or Oil; upon which Property depends that useful Invention of *Elæosaccharums*, occasionally mentioned above *, by means whereof we are furnished with a very advantageous Method of uniting Oils with Waters, Wines, Spirits, or all Manner of aqueous, vinous, or spirituous Liquors; so that such Liquors may be altered in their Flavours, and improved in their Virtues, at pleasure. For, by grinding a small Proportion of any essential Oil with dry Loaf-Sugar, the Oil is thus rendered miscible with any of the above mentioned Liquors, and at the same Time is no Way impaired, but rather improved in its Efficacy.

39. And thus we are taught an extemporaneous Method of making all those simple and compound Waters, whose Virtues depend upon the essential Oils they contain; which is the Case of most simple Waters, as those of Mint, Pennyroyal, &c. Nay, some simple Waters may be procured in greater Perfection by this Means than by Distillation, as it is commonly performed. Thus the simple Water of Baulm, for Instance, may be made better by means of the *Elæosaccharum of Baulm* and pure Water, than by simple Distillation, which in this Case brings over but little of the essential Oil.

40. And for compound Waters, they may be thus made to greater Perfection than we usually meet with them. For if only the first Part of the essential Oils that comes over be ground with Sugar, and introduced into a very clean Spirit, the Cordial Waters so prepared will be

* See *Leç. XI. Exp. I.*

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no way inferior to those distilled in the ordinary Manner. And thus Cinnamon-Water, Clove-Water, Nutmeg-Water, Citron-Water, &c. which depend upon the Use of but one Ingredient, may be readily made. And if compound Waters are required from several Ingredients, we need only have a compound *Elæosaccharum* at Hand.

41. These *Elæosaccharums* also, as they are easily made, either simple or compound, in great Variety, might help to improve the Art of Cookery, as affording the Virtues of Aromatics in a commodious Form, for several æconomical Occasions; and may thus be carried the longest Voyages without Danger of spoiling, or of having their Virtues impaired: an Inconvenience to which the natural Spices, though ever so well cured, are liable.

42. Again; A proper Set of these *Elæosaccharums* might afford a Variety of serviceable Medicines, that should have all the Qualities required in the best; that is, should be at once simple, parable, efficacious, and pleasant: For as essential Oils contain the specific Virtues of the Subjects, or those Qualities which constitute every Plant the Thing it is, they are of Consequence some of the most concentrated, powerful, restorative, and reviving Medicines hitherto known.

EXPERIMENT V.

The Way of Refining Tartar.

Tartar refined.

43. We took two Pounds of common white Tartar reduced to Powder, and put to it five Gallons of fair Water, in an earthen Pan, and setting it over the Fire to boil, we in the mean Time beat up the Whites of two or three Eggs, and

and whisked them in among the Liquor, which we afterwards skimmed and strained; then set it to shoot in an earthen Vessel, in a cool Place, for two Days, at the Expiration of which we found a Parcel of whitish Crystals sticking to the Sides of the Vessel.

44. This is a very troublesome and imperfect *Inconveniences.* Operation; for Tartar requiring twenty times its own Quantity of Water to dissolve it, the Vessels, the Fire, and the whole Apparatus, must of Necessity be large to refine a small Quantity of this Salt; which yet is not sufficiently refined at one Operation, though the Whites of the Eggs take up much dirty, and light earthy Matters, while the more ponderous sink to the Bottom upon standing. Hence the Operation must be several times repeated, before the Crystals will become perfectly white; which they will scarce ever do, if the Vessel wherein the Operation is performed be metalline; and Vessels of Earth, which this Salt does not corrode, being hard to procure so large as they are required for the Purpose, this adds to the Inconvenience.

45. It is true, for most Uses in Chemistry, *Remedied.* unrefined Tartar will answer as well as the refined, but for the Service of certain Arts, particularly Dying, it is required thoroughly purified: So that a more commodious Method of refining it should be endeavoured after, that we might at least be able to refine it in *England*, as well as they do in *France*.

46. Tartar is of a very particular Nature; being a solid and firm vegetable Salt, extremely hard to dissolve in Water, as containing much earthy and unctuous Matters, which defend it from the Action of Water: Whence we are directed to soften the Body of this Salt, or loosen
its

its Texture, in order to its more commodious Refinement. And this End may be obtained by a prudent Use of Lime-Water, or a weak Lixivium of Pot-Ash, or Salt of Tartar; as in the Making of *tartarized Tartar* *, where common Tartar is united with its own fixed Salt, and rendered easily soluble in a small Proportion of Water. But there need not be so much Alkali used for this Purpose, as to destroy the Acidity of the Tartar; and if too much should happen to be added, it may be mortified with Oil of Vitriol, so as not to prejudice the Salt.

The Experiment perfected.

47. But where an extremely pure and perfect Cream or Crystal of Tartar is required, we recommend the ordinary Crystals, or Cream of Tartar, to be dissolved in Water, made highly acid with rectified Oil of Vitriol; for if the superfluous Humidity be afterwards exhaled, the Tartar will thus shoot into perfectly transparent and beautiful Crystals, without at all participating of the Oil of Vitriol. And by the Help of these Directions common Tartar may be refined in great Perfection, and with no greater Trouble than the more soluble vegetable Salts.

Uses.

48. When the Powdered Crystals of Tartar are mixed with half their Weight of Salt of Tartar, and dissolved together in boiling Water, they make a very extraordinary neutral Liquor, or *Menstruum*; and by Evaporation a neutral Salt of very uncommon Properties. This Salt easily runs in a moist Air; and will powerfully assist in extracting the resinous or oleaginous Parts of Vegetables, by being boiled with them in Water. The aqueous Solution of this Salt will dissolve the tough Bodies even of Myrrh, Gum-

* See below § 48.

Lac, and is much better fitted than Salt of Tartar for many of the same Purposes where that Salt is commonly employed. This neutral Salt, or tartarized Tartar, is excellent in healing Wounds, and cleansing Ulcers : It is an agreeable and successful Purgative in hypochondriacal Cases ; and, dissolved in Water, makes a pleasant Kind of *Purging Water*. Its Virtues and Powers, both as a Menstruum and a Medicine, seem not hitherto sufficiently known ; whence we recommend it to farther Experience.

EXPERIMENT VI.

The Method of Refining Nitre, or Salt-Petre.

49. We dissolved four Pounds of rough Nitre, ^{Nitre refined.} as it comes to us from the *Indies*, by boiling it in as much Water as would commodiously suffice for that Purpose ; then set it to shoot for two or three Days in a covered Vessel of Earth, with Sticks laid across for the Crystals to adhere to. These Crystals being afterwards taken out, were drained and dried in the open Air.

50. This seems to be the best and simplest Method of purifying Nitre ; for thus, by its own natural Property of crystallizing, it shoots pure from the Sea-Salt, or other Foulness that is apt to mix among it. However, if the Nitre prove unctuous, it may be proper to add a little lixivium of Pot-Ash, Lime-Water, or Allum. And if by this Means it does not become sufficiently pure for making the best Gun-powder, or *Aqua Fortis*, it must be dissolved again, and recrystallized, in the Manner of our present Experiment ; which being repeated, with a larger Proportion of Water than before, evaporating slowly

slowly and suffering the Salt to shoot in a moderately warm Place, without the free Admission of the external Air, the Nitre will be obtained in its utmost Purity and Perfection. It is judged to be pure, when being thrown upon live Wood Coals, it fulminates briskly, and will then make perfect Gun-powder and *Aqua Fortis*.

*History of
Nitre.*

51. The chemical History of Nitre is still defective. This History should shew, by what Means Nitre is procurable from all animal and most vegetable Matters: For there are many Experiments and Observations which seem to prove, that Nitre originally proceeds from putrified Vegetables; that many uncorrupted vegetable Subjects contain it in a large Proportion; and that all animal Subjects contain a *semivolatile Nitre*; which may be rendered more fixed, or like the common, by the Addition of Pot-Ash or Quicklime *a*).

52. To those disposed to enter upon this useful Enquiry, we recommend a full Knowledge of the Methods now in use for procuring Nitre from certain Earths that are dunged by Animals, and putrefied Vegetables; the shortest Ways of separating the unctuous Matter from the Nitre, which occasions all the Difficulty; and a due Comparison of the Process for procuring and refining of Nitre with that for procuring and refining of Sugar. There is Reason to believe, an Enquiry of this Kind might be attended with such Success, as to shew that Nitre is not peculiar to any one Country, but obtainable in Plenty, wherever animal and vegetable Subjects abound *b*).

a) See Mr. Lemery's Papers upon this Subject in the French Memoirs. See also Dr. Stub's *Legends no Histories*.

b) See Glauber's *Prosperity of Germany*.

EXPERIMENT VII.

The Method of Making Pot-Ash.

53. Having burnt a Quantity of common Billet-*Pot-Ash* Wood to grey Ashes, we took several Pounds *prepared.* of those Ashes and boiled them in Water, so as to make a very strong *Lixivium*, or *Lie*. This *Lie* we strained thro' a coarse Linen Cloth, to keep out any black Parts of the half-burnt Wood that might happen to remain in the Ashes; then we directly evaporated this strained *Lie* in an Iron-Pan over a quick Fire, almost to Drieness. We took out the Matter remaining at the Bottom, and putting it into an Iron-Crucible, set it in a strong Fire till the Matter melted; and then immediately poured it out upon an Iron-Plate, where it soon cooled, and appeared in the Form of a solid Lump of Pot-Ash.

54. And much after this Manner is Pot-Ash *Use.* made in the large Way of Business, for the Service of the Soap-Boiler, Glass-Maker, Fuller, &c. But according to the Difference of the Wood or combustible Matter employed, with the Manner of burning it, and conducting the Process, different Kinds of Pot-Ash are prepared.

55. There are certain saline Plants that yield *And ap-* this Pot-Ash to great Advantage, as particu-*plication.* larly the Plant *Kali*; there are others that afford it in less Plenty, and of an inferior Quality, as Bean-Stalks, &c. But in general, all vegetable Subjects afford it of one Kind or other, and may most of them be made to yield it tolerably perfect, after the Manner of our present Experiment; even the Loppings, Roots, and refuse

refuse Parts of ordinary Trees, Vine prunings &c.

Difference.

56. But besides the Difference found in different Vegetables for producing this Salt, as some may naturally contain more or less of the saline, oily, or earthy Principle, *than others*; another Difference will arise from the Manner of burning the Subject, according as that is done with a greater or less Degree of Fire, or Admission of the Air. If a vegetable Subject be burnt in a close, stifling Manner, to a grey, or somewhat blackish or brown Ash, these Ashes thus containing more of the Oil of the Subject, will afford a more unctuous Salt, that easily melts in the Fire, and is better fitted for the ready making of Soap. But if the Subject be burnt in the open Air, so that it have every Way free Access thereto, the Ashes will be white, or contain no Part of the Oil of the Subject; and thus the Salt will difficultly melt in the Fire, and prove fitter for the making of Glass (where no Oil is required) than of Soap.

57. A third Difference in Pot-Ash arises from the Length or Shortness of Time it is detained in the melting Fire; whereby it becomes either of a grey, white, bluish, or greenish Colour; grey or white if it be soon taken out; and bluish or greenish if long detained therein. And according to these Differences Pot-Ash is more or less sharp or strong; a longer Continuance in the Fire always consuming the more unctuous Parts, and leaving the saline ones more naked: provided no considerable Proportion of Earth remain mixed with the Salt, which in that Case would soon be vitrified, or turn to Glass, and have no saline Property at all.

* See *Let. VIII. passim.*

58. The fixed Salts of all Vegetables, when reduced to absolute Purity, or entirely separated from the other Principles, appear to be one and the same Thing; at least not manifestly to differ*. Whence it should seem that, by a suitable Management, good saleable Pot-Ash might be made in all Places where vegetable Matters abound: For if, by examining *Russia* Pot ash, for Example, we find, that its superior Excellence depends upon its being clear of Earth, or upon its containing a large proportion of Oil, or fixed Salt; these Advantages may, by properly regulating the Operation, be given to *English* Pot-Ashes, so as perhaps to render the latter as good as the former. But where the Pot-Ash of any remarkably saline Vegetable is to be imitated, as that of *Kali* suppose, we would recommend a prudent Sprinkling of the Subject with Salt or Sea Water in the Burning. And by these Ways properly diversified, any Principle that is naturally wanting in the Subject might be artificially introduced, so as to perfect the Art of Pot-Ash, on which the Art of Soap-making depends.

59. For to make Soap requires an intimate Union of the Salt of Pot-Ash with Oil, or any vegetable or animal Fat. This Union in the present Method of Soap-making is procured by a tedious Operation, or by long Boiling a weak Lie of Pot-Ash and Quicklime with the Fat; adding a stronger and a weaker Lie occasionally by degrees, till the Point requisite to the Perfection of the Soap is hit.

60. It might greatly contribute to shorten this Operation and ease the Expence thereof, if a mechanical Motion or Engine were employed instead of Fire, to procure this intimate Union of

* See *Let. VIII.*

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the Lie and Oil. And that something of this Kind is practicable appears from hence, that if, for Example, half a Pint of the Soap-boiler's strongest, or *Capital Lie*, as they call it, be briskly shook in a Phial, with an Ounce or more of Oil-Olive, for half a Quarter of an Hour, and then the Phial be suffered to rest, there will, in a short Time after, be found a solid Cake of tolerable Soap at the Top of the Liquor; and may be easily preserved in that Form by breaking the Phial, and rendered harder by being exposed to the Air.

History of Soap. 71. We could wish that the *Chemical History* of Soap were extant; for it should seem that many Advantages might be thence derived to particular Arts and Trades. This History is a Thing of larger Extent than will be generally apprehended, as containing three large Branches; (1) the *History of Pot-Ash*; (2) the *History of Oils and Fats*; and (3) the *several Ways of uniting them to advantage*.

62. (1) The *History of Pot-Ash* would shew wherein the Superiority of the foreign Ashes, particularly those of *Marseilles*, *Castile*, *Venice*, and *Joppa*, consists; why the Soaps at present made in *England* fall short of Perfection; and possibly inform us of the Ways whereby even *Joppa* Soap might be equalled in *England*. For such a History would trace out the real physical Differences betwixt one Sort of Pot-Ash and another, and the Ways of converting any one of them into the rest*, so as to fit them for the Soap-boiler, Glass maker, &c. respectively; it would shew how the mildest Pot-Ash is obtainable, for the more curious Soaps, and especially for those intended to be used medicinally, &c.

* See above, § 62—65.

And,

And, by the Way, there is Room to suspect that a thorough Enquiry into this Subject would shew the Matter of all Pot-Ash to be the Matter of Nitre; or that all the Vegetables which yield Pot-Ash by *Calcination*, might be brought to afford Nitre by *Putrefaction*; or that Pot-Ash is nearly the same Thing, both in Nature and Substance, with *fixed Nitre* *.

63. (2) The *History of Oils and Fats* would also shew how one Sort might be converted into another, or hard animal Fats into liquid Oils, and liquid Oils into solid Fats, by digesting Oils with certain coagulating Acids, &c. how all the foreign solid Oil-Soaps might be imitated in *England*; and how a great Variety of *liquid Soaps* might be prepared for many different Purposes; the Foundation of the Thing entirely depending upon the Use of a highly subtilized, and thin *vegetable Oil*.

64. (3) The *History of uniting fixed vegetable Salts with Oil*, might describe several Machines for the Purpose; whereby many Tuns of Soap should be readily made by Means of Mills, wrought by the Wind or Water; and this either with or without Fire. It might also inform us of several *Menstruums*, or *connecting Mediums*, which should, either alone, or with little Assistance, procure an intimate Union. And that something of this Kind is practicable, we are assured by particular Experiments.

AXIOMS and CANONS.

1. We learn from the foregoing Enquiries, that large Quantities of Oil may lie concealed

* See Glauber's *Prosperity of Germany*; and M. Lemery's Papers upon *Nitre* in the *French Memoirs*.

in Bodies apparently dry; where neither the Eye, nor any of the Senses, can perceive the ordinary Signs of Oil *a*).

2. That Oils gained by Expression are apt to turn rancid, and become unwholsome, by Heat: Whence they should always be kept cool, and not be drawn by the Means of Fire, if intended for curious or internal Uses *a*).

3. That much Oil may be separated by boiling Water from Subjects that have already felt the utmost Force of the Press: Whence an Eye should be had upon the Cakes of Lint-seed, Mustard-seed, &c. for obtaining a farther Oil, after they have been once squeezed *a*).

4. That the oily Substance of Nuts, Almonds, and the like vegetable Subjects, is soluble in Water, by bare Triture, into a vegetable Milk, having a great Affinity with the Milk of Animals *a*).

5. That *expressed Oils* may be readily changed, or improved, in their Colours, Tastes, and Odours; so as that any one of them may afford a great Variety of apparently different Kinds *a*).

6. That aromatic Vegetables yield an *essential Oil* by Distillation with Water; which Oil contains the essential or specific Taste, Smell and Virtues of the Subject *b*).

7. That the *native Spirits*, or fine odoriferous Parts of Vegetables, are readily imbibed, and long preserved, by expressed vegetable Oils *a*).

8. That the Difference betwixt the *artificial* and *natural essential Oils of Vegetables*, depends upon the different Fixedness or Volatility of their direct unctuous Parts *b*): Whence we are directed to a Way of introducing the *native Spirits* of

a) Exp. I.

b) Exp. II.

Plants into finer or lighter Oils than the common expressed Kinds; so as perfectly to imitate, or exceed, the natural essential Oils.

9. That there are sure Methods of discovering several fraudulent and abusive Kinds of Adulteration in *essential Oils*; but that a more curious Adulteration is practicable, so as to elude the common Trials *a*).

10. That every *essential Oil* has its determinate specific Gravity: Whence, if a Table of their specific Gravities were formed, from a known genuine Set, such a Table might be of Service in detecting the Frauds or Debasements frequently practised in these Oils *a*).

11. That several Cautions are required to extract the *essential Oils* of aromatic *Indian Vegetables* to Advantage; which Cautions being duly observed, such Oils may be obtained in *England*, perhaps as perfect as in the *Indies a*).

12. That a highly attenuated Oil is, by repeated Rectifications, obtainable from the gross, fetid, and empyreumatic Oil of vegetable and animal Subjects *b*).

13. That the gross, empyreumatic, *animal Oils* may, by Digestion with fixed Alkalies, afford volatile Salts *b*).

14. That the Matter of *Sugar* is, originally, a vegetable Juice, apt to grow sour with Heat, and not reducible by bare Boiling to solid Sugar, but only to a mellaginous or treacly Substance *c*).

15. That many other vegetable Juices, as particularly those of the Birch and Sycamore Trees, the Rob of Malt, of Raisins, &c. are convertible into good Sugars, by the same Means that are used in the ordinary Sugar-making *c*).

a) Exp. II.

b) Exp. III.

c) Exp. IV.

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16. That the Art of refining Sugar, so as to make it rocky, perfectly white, spangly and resplendent, principally depends upon a prudent Choice and Use of Lime-Water *a*).

17. That refined Sugar renders *essential Oils* instantaneously miscible with Wines, Water, and Spirits; so as to afford a ready Means of improving several Arts *a*): Or that the proper Introduction, Use, and Application of *Eleosaccharums*, may improve the Art of Distilling, Pharmacy, Wines, Cookery, and Medicine *a*).

18. That the troublesome Art of *refining Tartar* may be shortened and improved by the Use of Alkalies and Oil of Vitriol *b*).

19. That Tartar is convertible into a very different Salt, by being united with its own fixed Salt; so as hence to become a powerful Menstruum, and a valuable Medicine *b*).

20. That CrySTALLIZATION, once or twice repeated, is a sure Method of refining Nitre, or *Salt-Petre* *c*).

21. That Nitre is not originally a fossil, but a vegetable Salt; and thence to be found in animal Subjects *d*).

22. That a full Enquiry into practicable Methods of procuring Nitre directly from vegetable and animal Subjects, may be attended with Success *d*).

23. That serviceable Pot-Ash may be made in any Place that abounds with vegetable Subjects *e*),

24. That the Art of making Pot-Ash is improveable by chemical Knowledge, to the Advantage of the several Arts thereon depending *e*).

a) Exp. IV. *b*) Exp. V. *c*) Exp. VI. *d*) Exp. VI. and VII. *e*) Exp. VII.

25. That

25. That in particular, the Art of Soap-making may be brought to much greater Perfection in *England*, by Means of a mixt chemical and mechanical Enquiry *a*).

LECTURE XIV.

C O N T A I N I N G

Attempts to illustrate and improve the Business of Colours, Dyes; and Stains.

1. **O**UR present Business is to discover the *The Subject.* Means of producing, varying, changing, and destroying the Colours of Bodies; with a View to improve the several Arts that depend upon the Use of Colours, Dyes, and Stains *b*).

2. This we shall endeavour to perform by *The Means.* Means of Experiments, first upon Light, and then upon selected Subjects of the vegetable, animal, and mineral Kingdoms; in order to find out the physical Causes of the Effects produced.

3. The *first* Experiment therefore will shew, *The Heads* that common Light is separable into several *of the Ex-* Colours: The *second* will be collective, or afford *periments.* a Variety of Instances to prove that the Colours of Bodies depend upon a certain Disposition of Parts, fitting them to reflect the differently

a) *Exp. VII.*

b) The present *Lecture* was not publickly read, as the rest were; a clear sun-shiny Day, which the Experiments require, not happening at the Time.

coloured Rays of Light: The *third* principal Experiment will exhibit the Method of obtaining those *vegetable Colours* commonly called *Laques*: The *fourth* will teach the Way of preparing a certain animal Colour called *Prussian Blue*: and the *fifth* will shew the Way of preparing a metalline Colour, for tinging Glass red, &c.

EXPERIMENT I.

That the Rays of Light are compounded, and separable into seven distinct Kinds or Orders of Light, on which all Colours depend.

A leading Experiment, with the Prism.

The Prismatic Colours.

Not farther resolvable.

4. (1) Having darkened a Room, by shutting up all the Windows, and bored a small Hole in a Shutter opposite to the Sun; if a Glass Prism be now properly placed against this Hole, we find that an oblong and variously coloured Image of Light will be thrown upon the Ceiling, or farther Wall of the Room. (2) If this Image of Light be carefully examined, it will appear to consist of seven distinct Colours, or different vivid Lights, which are constantly found in the same Order; *viz.* Red in the first Place, Orange in the second, Yellow in the third, Green in the fourth, Blue in the fifth, Violet in the sixth, and Indigo in the seventh: But a slight View distinguishes only five principal Colours; *viz.* Red, Yellow, Green, Blue, and Violet. (3) If these several coloured Lights be separately received upon another Prism, in the same Manner as the Sun's Rays are by the first, they suffer no farther Division, or Resolution, but remain invariably the same: And this they do whatever figured Glass, Crystal, or Diamond be made use of. (4) But if the whole Number of

of these differently coloured Rays be received, from the first Prism, upon a *Lens*, or double convex Glass, in the Room, they are thus blended together again, and may be thrown upon Paper, or any other Body, placed at a due Distance, so as to form a Spot of white and bright Light in the Focus of the convex Glass. (5.) If the red Rays be separately received by an opake white Body, that Body appears to be red; if the yellow Rays be separately received in the same Manner, by an opake white Body, the Body appears to be yellow; and so of the other Colours respectively: A red Body appears more vivid, or intensely red, in the red Light; a blue Body more vivid, or intensely blue, in the blue Light, &c. But all coloured Bodies appear more dead or languid in Lights of different Colours from their own; as a red Body in a blue Light, &c.

Compound white Light.

Objects assume the Colour of the Light.

5. This general Experiment is the Foundation of Sir *Isaac Newton's* Doctrine of Light and Colours*; and may shew, (1.) that the Sun's Light is not a simple Thing, but compounded of seven different Orders of coloured Rays; all which being exquisitely blended together, constitute a perfectly white Light: (2.) That these seven Orders of Rays are differently refrangible; that is, differently disposed to be turned out of their Way, in passing from one transparent Body into another; the red Rays least, the Violet most, and the rest in their Order as mentioned above: Which is the physical Reason of the Division of Light into these seven Orders of Rays, and that there are no more than seven original Colours of Light: (3.) That Bodies appear of the same Colour with the

Light a Compound

Of seven Colours.

* See his *Optics*, *passim*.

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The Colours of Bodies from Light. White and Black no Colours.

Colours of Bodies whence.

Order of Rays they reflect, or turn back, into the same Medium from whence they were received: (4.) That White and Black are no true Colours; but White an equal Reflection of all the original Colours, and Black the Absorption of them all; for if they were returned, either mixed or unmixed, Whiteness, or some of the seven original Colours of Light, and not Blackness, would appear: (5.) That the Variety of Colours in natural Bodies proceeds from their differently reflecting or refracting the Rays of one, two, or several Orders, more than the rest. Thus the Bodies denominated red chiefly reflect the red Order of Rays; those denominated blue Bodies chiefly reflect the blue Rays of Light; and are thence said to be red, blue, &c. And all the mixed Colours of natural Bodies arise from their reflecting two or more Orders of Rays together, and absorbing or stifling the Rest.

EXPERIMENT II.

Or, collective Instances to shew that Transparency, Whiteness, Blackness, and Colours, as considered in Bodies, depend upon certain particular Structures, Textures, or Arrangements of the Parts of Bodies; differently disposing them to transmit, reflect, refract, or absorb the Rays of Light.

The Texture of Bodies changed by Trisure.

6. (1.) Glass, Crystal, Diamonds, Nitre, Borax, and other transparent solid Bodies, lose their Transparency, and appear white, upon their being reduced to Powder; that is, by a bare Alteration of their gross Texture, or a simple Reduction to smaller Parts, so as to make them reflect many of the Rays of Light which they before transmitted. And the same holds of the Whites of Eggs whisked up to a Froth, frothy Water, &c.

7. Black

7. Black Talc, by being made red hot in the *By Fire.* Fire, is turned of a Gold Colour; Syrup of Violets, by a boiling Heat, loses its beautiful Violet Colour, so as at length to become pale, or colourless; white Loaf-Sugar, being barely melted over the Fire, without Water, immediately changes its Whiteness, and becomes brown, or, by a longer Continuance, black; so that a single Grain of this black Substance will tinge a Pint or a Quart of fair Water, or colourless Brandy, of a beautiful yellow, brown, or straw Colour; for which Purpose it is used by Distillers, and others *a*).

8. All the finer coloured Flowers, as Violets, *By the Air.* Carnations, Roses, &c. lose their Colours barely by being exposed to the open Air for any long Time; so as at last to appear perfectly discharged, or white; as if they had been exposed to that particular Discharger of Colours, the Fume of burning Brimstone. And the same is remarkable of the finer or lighter Kinds of Colours in Silks, or the light Blues, Yellows, and Reds, particularly the light grain-coloured Silks; all which Colours are gradually changed, discharged, or abolished, in wearing, or by the Silks being long exposed to the Action of the Air *b*). But the Scarlet Colour is more fixed and durable. And, in general, the deeper any Colours are, the more fixed and durable they prove; as being thus not Shades, as the Pinks, light Blues, &c. are, but true Colours, corresponding to the original Colours of Light. Add to this, that Dyers constantly find their Colours prove brightest, or strike to the best Advantage, when the Air is clear *b*). Lastly, the blue essen-

a) See *Lect. II. and XII.*

b) See *Lect. III. passim.*

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tial Oil of Camomile-Flowers loses its Colour, and changes to a dirty Green, by being exposed to the Air.

By Water. 9. Different Waters strike different Colours with the same tinging Ingredients. Thus irony Waters turn black, or inky, with Galls, Green Tea, &c. And Dyers find some certain Waters more proper for their Purposes than others. And, in general, the purest and lightest Waters strike the best Colours with Dying-Stuffs. And hence it is that such Waters as have, by long standing, putrified, or fermented, and purged themselves, or been filtered thro' the common Filtring-Stone, or Sand, are found to extract and communicate Colours to the greatest Advantage *.

By Salts. 10. Salts having a Power to alter the Textures of Vegetables, do consequently produce Changes of Colours therein. Thus most Flowers, whether blue or red, as Violets, Roses, &c. turn green with *Alkalies*; but Violets turn red, and red Roses have their native Redness greatly heightened by *Acids*. So again, the yellow Roots of Rhubarb, Turmeric, &c. are heightened, or made redder, by *alkaline Salts*.

The Texture of Metals less alterable. 11. As Metals have a strong Texture in their metalline Form, so they preserve their natural Colours durably, unless corroded or dissolved by their particular Menstruums; after which, their Solutions strike particular durable Colours, or afford the strongest *Stains*.

Iron. 12. Iron dissolved in stale Small-Beer gives the beautiful Yellow used in Callico-Printing; when sublimed with *Sal-Armoniac* it also affords a Yellow. And the common Iron-Moulds made by Ink, are owing to the Iron dissolved in the

* See Lect. V. *passim*.

Copperas,

Copperas, whereof the common Black Writing-Ink is made.

13. Copper melted with Zink appears of a *Copper*. Gold Colour; dissolved in *Aqua-Fortis* it affords a beautiful Green; and in any urinous Spirit, a beautiful Blue; and the Solutions may be reduced to dry Colours, by Crystallization, or Evaporation. The same Metal precipitated with common Salt, out of *Aqua-Fortis*, gives the Turquoise Colour to white Glass, when melted therewith.

14. Tin, a white, or colourless Metal, affords a light blue Colour, by being fluxed with Antimony and Nitre. The same Metal is necessary in striking the Scarlet-Dye, with *Aqua-Fortis* and Cochineal. Its Calx turns, by strong Fusion, to a Glass of the opal Colour.

15. Lead, being corroded by the Fumes of *Lead*. Vinegar, makes the fine White called *Ceruse*, and the white Fucus called *Magistery of Lead*; being calcined in a strong naked Fire, it becomes Minium, or Red Lead; and this melted into Glass with Sand, is the Foundation of the Art of imitating all the coloured Gems: For this Glass itself will resemble the Hyacinth, and by the Addition of prepared Gold and Tin, the Ruby *a*); the Sapphire with Cobalt, the Emerald with Iron and Copper, the Amethyst with Gold, and the Granat with Iron, &c. *b*).

16. Silver, another white, or colourless Metal, *Silver* being dissolved in *Aqua-Fortis*, if Chalk is put to the Solution, turns of a beautiful Purple, or Amethyst Colour: And its own Solution, tho' pale as Water, durably stains the Nails, the Skin, the Hair, and other animal Substances, brown or black.

a) See below Exp. V. *b*) See Neri's *Art of Glass*; and Mr. Boyle's *Philosophical Works*, *passim*.

*Quick-
silver.*

17. Quicksilver mixed with Brimstone makes a black Mass; and this, by Sublimation, affords the beautiful red Pigment called *Cinnabar*, or Vermillion: and the Solution of Quicksilver, being precipitated with common Salt, yields a snow white Powder; which also turns black, by being mixed with Sulphur.

Gold.

18. Gold, dissolved in *Aqua Regia*, affords a fine yellow Liquor; which stains animal Substances beautifully purple: And if the Solution be sufficiently weakened with Water, and mixed with a Solution of Tin, a fine red or purple Powder may be thus obtained for staining Glass most beautifully red *a*).

Minerals.

19. Many mineral Subjects are natural Pigments; as native Cinnabar, Ochre, Black Lead, &c. but particularly the yellow Earth called *Light Ochre*, found in *Shottover Hills*, which is used native as a light Yellow, and by Calcination makes a light Red. This Colour *England* supplies *Italy* with; and *Le Gar* would frequently say he had been no Painter without it *b*).

Experimental Instances of Colours produced, destroyed, and regenerated upon simple Mixture.

*A colourless
Liquor af-
fording
Colours by
Mixture.*

20. (1) Put dry red Rose-Leaves into Spirit of Wine, and, by standing a little therein, the Rose-Leaves will lose their red Colour, without manifestly tinging or altering the Liquor; then add a little Oil, or Spirit, of Vitriol thereto, and the Liquor will appear of a red Colour. But if a little alkaline or urinous Spirit be poured to the Mixture, the red Colour presently changes to a Green; which, by the Addition of a

a) See hereafter, *Exp. V.*

b) See below, *Exp. V. § 67.*

little more Spirit of Vitriol, turns to a red Colour again.

21. (2.) Make a slight Infusion of bruised Galls in Water, so as not to discolour the Water; filtre the Infusion; make also a weak Solution of Green Vitriol in Water, and filtre the Liquor, so that they may both appear pellucid: These Liquors being now mixed together, an inky Blackness will immediately arise; but if a little Oil of Vitriol be added to the Mixture, the Blackness will, by Degrees, totally vanish, and the Liquor appear pellucid again; tho' the Blackness may be recalled by the Addition of a little Salt of Tartar.

22. (3.) If a little bruised Camphire, which is a very white Substance, be put into pellucid Oil of Vitriol, and the containing Glass be shook for some Time, the Camphire will dissolve, and gradually change the Mixture to a Brown, and at length to a full Black. But upon the Addition of fair Water, the Blackness entirely vanishes, and the Camphire rises to the Top in its pristine Form, and native Whiteness *.

23. (4.) If the Shavings of *Lignum Nephrificum* be infused for some Time in cold Water, and the clear Liquor be decanted into a clean Glass, and viewed from the Light, the Liquor will appear of a beautiful Blue; but if viewed towards the Light, of a Yellow. If a little Spirit of Nitre be put to this Liquor, it loses its Power of reflecting the blue Rays; but the Addition of a little Oil of Tartar, *per deliquium*, recovers that Power again.

24. (5.) If Logwood be infused in Water, it gives a red Colour; which, upon the Addition

* It is remarkable, in this Experiment, that the strong Scent of the Camphire is absolutely wanting in the black Solution; but recovered upon the Addition of the Water.

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of a little Spirit of Urine, turns to a fine Purple : But this may be changed to a dilute Red, by dropping in a little Spirit of common Salt.

Red Colours brightened and lowered by Mixture.

25. (6.) An Infusion of *Brazil* Wood, or *Cochineal*, in Water, is much hightened in its red Colour, by the Addition of Spirit of Urine ; and lowered or turned paler by the Spirit of Salt.

A pellucid Liquor made blue by a white Body.

26. (7.) If Spirit of Wine be digested upon recent *Camomile-Flowers*, and distilled over from them in a Glass Retort, the Spirit will thus acquire a beautiful blue Colour, which may be made deeper by being drawn over again from fresh Flowers.

A blue Colour destroyed by Mixture.

27. (8.) A beautiful blue Tincture being made by digesting Spirit of Urine upon Filings of *Copper*, the Addition of a little Oil of *Vitriol* entirely destroys the blue Colour ; as a little Spirit of Salt turns it to a Green.

Pellucid Liquors made red by Mixture.

28. (9.) Pellucid Oil of *Vitriol* being mixed with pellucid Oil of *Turpentine*, or the essential Oil of *Aniseeds*, or more particularly with Oil of *Cloves*, they turn thereupon into a thick, red Balsam. And so again, if a pellucid common Oil be, by Means of a little Wax and continued Triture, gradually mixed with fair Water, they unite into a very thick, white Substance, Balsam, or cold Cream.

A white Powder made yellow by Mixture.

29. (10.) Oil of *Vitriol* being distilled over from *Quicksilver*, leaves a white Powder behind ; to which if Water be poured, the Powder presently becomes of a beautiful Yellow.

The same Solution affording differently coloured Precipitates.

30. (11.) To a Solution of *Quicksilver* in Spirit of *Nitre*, add Spirit of Urine ; and a white Powder will be precipitated : To another Parcel of the same Solution add Oil of *Tartar per deliquium*, and a yellow Powder will fall to the Bottom : To a third Parcel of the same Solution add

add Spirit of Urine, and the Precipitate obtained will be of a Flesh-Colour.

31. (12) If a clean new Pen be dipped in *Limpid Ink* Spirit of Vitriol, and the common deep Blue *appearing* Paper be wrote upon therewith, the Letters ap- *red.* pear of a very bright and beautiful Red : And, in the same Manner, pellucid Spirit of Salt stains a black Hat red.

32. (13) A pellucid Solution of *Saccharum Invisibile* Saturni in Water, being wrote with, becomes *Ink.* invisible upon the Paper, when dried : But the bare Fumes of another transparent Liquor, viz. an Infusion of Quicklime and Orpiment in Water, will soon render the invisible Writing black and legible. And thus those commonly called Invisible or Sympathetic Inks are made.

33. (14) The volatile Salt of Sal-Ammoniac, *A white* a white Body, and the Crystals of Copper, a *and green* green one, will, by Mixture, become Purple. *Body makes* Purple.

34. (15) Salt of Steel, a green Body, and *A Green* Sugar of Lead, a white one, being mixed toge- *and White,* ther, the Surface of the mixt Powder will ap- *red on the* pear red ; whilst the internal Parts are of a dirty *Surface.* White.

35. (16) That original, and simple, as well as compound, Colours, are producible by Mixture, appears from many Experiments.

36. (17) If the Sun's Rays pass thro' two, *A Green* Pieces of differently coloured Glass, for Instance, *from Light* a blue and a yellow Piece, laid upon each other, *passing* and these Rays be received from the Glasses *thro' blue* upon white Paper, they then appear of a beau- *and yellow* tiful Green. *Glass.*

37. (18) It is common with the Dyers, to *Greens* dye the Cloth first Blue with Woad, and turn *died from* that Blue into a Green by the Yellow called *blue and* *yellow.* *Dyer's Weed, or Luteola.*

38. (19)

*Green from
a blue and
yellow Li-
quor.*

38. (19) To a fine yellow Solution of pure Gold, in *Aqua Regia*, add a deep blue Solution of Copper in Spirit of Urine; and the Mixture will appear green.

*From blue
and yellow
Ammel.*

39. (20) Blue and yellow Ammel, being melted together, constitute a green one.

*Many
Painter's
Colours by
Mixture.*

40. (21) The Painters make a great Variety of compound Colours, by mixing two, three, or more different Colours together, either on their *Pallat*, or on the Canvas.

*Mixed Co-
lours may
make
White.*

41. (22) A Mixture of the seven original Colours, or even five of them, will make a White; and the more perfectly, the finer and more perfect the coloured Bodies are. Thus, if a large Top be painted on its upper Surface, one Part red, another yellow, another green, another blue, and another violet; this Surface, whilst the Top is spinning briskly (so that the Motion shall confound the several Colours, or make them appear mixed to the Eye) will exhibit a dirty Kind of Whiteness. And in like Manner, by mixing together Powders of different Colours, as Vermillion, Orpiment, Indigo, Verdigrase, &c. in proper Proportions, the compound Powder will, in a strong Light, appear to be white. And if differently coloured Flames could be brought to mix, this Experiment might be made in greater Perfection.

*Flames of
different
Colours.*

42. (23) Flames are of different Colours, according to the Bodies that produce them. Thus the Flame of burning Camphire is white, like the Focus of a Burning-Glass; the Flames of Spirit of Wine, and of Sulphur, are blue; the Flame of white Wax is white, inclining to blue; that of Tallow, white, but rather inclining to yellow, &c. Whence proceeds the Difference of the Colours of Bodies, as viewed by Day-light, Candle light, Fire-light, sulphureous Light, &c.

Et. And, for making Experiments to this Purpose, Oil might be impregnated with certain Metals, as particularly Copper and Iron, by Triture, and Digestion, so as to exhibit their particular Flames.

43. (24) The Prismatic, or original Colours *The Prismatic Colours imitated.* may be imitated to considerable Perfection in Liquors, where the Parts of the tinging Substances are rendered extremely minute or fine. Thus a Solution of Cochineal in Spirit of Urine, viewed in a strong Light, affords a most vivid and beautiful Red; a Solution of Copper in Spirit of Urine, yields a glorious Blue; a Solution of Verdigrease in distilled Vinegar, is an excellent Green; a Solution of Gold in *Aqua Regia*, makes a fine Yellow; an Infusion of Violets in hot Water, affords an excellent Violet Colour, Et. And from a thorough Acquaintance with these Liquors, and the Methods of varying, mixing, and heightening their Colours, many Improvements in the Arts depending upon Colours, Dyes, and Stains, might be rationally expected.

44. (25) The foregoing Set of Experiments *Result of the Experiments.* not only confirms the former leading Experiment made with the Prism, but also Sir *Isaac Newton's* general *Doctrine of Colours*: For it is hence manifest, that slight mechanical Alterations in Bodies, produce, alter, or abolish all Kinds of Colours therein; or that all the Colours of Bodies are only original Colours of Light, differently reflected, either in a simple or variously compounded State, according to the particular Disposition, Texture, Mixture, or Arrangement of the small Parts of the reflecting Body, so as to afford that infinite Variety of Colours we meet with in natural and artificial Things.

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EXPERIMENT III.

The Method of preparing the vegetable Colours called Laques.

*The Laque
of Turme-
ric.*

45. Take a Pound of Turmeric-Root, reduced to fine Powder, three Pints of fair Water, and an Ounce of Salt of Tartar; put them into a glazed earthen Vessel, and let them boil together, gently, over a clear Fire, till the Water appears richly impregnated with the Turmeric, or will stain a Piece of white Paper beautifully yellow; then filtre the Liquor, and gradually add to it a strong aqueous Solution of Roch-Allum, till the yellow Matter is all curdled together, or precipitated: After this, pour the Whole into a Filtre of Paper; where the aqueous Part will run off, and leave a yellow Matter behind; which beingedulcorated, or washed in the Filtre, by the repeated Affusion of fresh Water, till the Water comes away infipid, and afterwards dried, becomes the *Laque of Turmeric*, or a beautiful yellow Colour for Painting.

*The gene-
ral Way of
obtaining
Laques.*

46. This Experiment shews a general Method of obtaining a Laque from all the vegetable Subjects fitted to afford it: For in the same Manner may a red Laque be made from Madder, Brazil, and many other dying Woods, or tinging Vegetables. But where the Colour of the Subject depends upon a very subtil Texture, Mixture, or Arrangement of the Parts, this Method destroys, or at least impairs, the Colour; as particularly in Violets, Red Roses, Carnations, &c. So that it seems applicable only to the tinging Vegetables of a somewhat strong and firm Texture.

47. In

47. In some Cases also a simpler Process is ^{The parti-} sufficient to obtain rich *Laques* particularly ^{cular La-} that beautiful red one emphatically called *Laque*; ^{que of} and from which the Name seems to be derived ^{Stick-Lac.} to the rest. This red *Laque* is obtained barely by boiling *Stick-Lac* in Water; then filtering the Decoction, and evaporating the superfluous Humidity: For the beautiful red Colour adheres to the Outfides of the Sticks broke off the Trees, along with the *Gum-Lac*; and readily communicates itself to boiling Water *. As some of this tinging Matter likewise sticks to the Gum itself, it is proper to boil them both together: For the Gum does not prejudice the Colour, nor dissolve in boiling Water: So that after the Operation the Gum is as fit for the making of Sealing-Wax, or other Uses that do not require the Colour, as it was before.

48. And much after the same Manner is that ^{Carmine.} extremely rich and beautiful red Colour called *Carmine* prepared from Cochineal and a Solution of Tin; for Carmine may be conceived as no more than the Scarlet, or Bow-Dye Liquor, concentrated, or reduced to what the Painters call a *Body*.

49. How far our present Experiment may be ^{Extension} applicable to other Parts of the *Materia tinctoria*, ^{of the Ex-} seems not hitherto well considered. Doubtless ^{periment.} it might afford a great Variety of *new Colours*, by a proper Extension and Diversification in the *Menstruum* and *Method*. For Example: If *Red Saunders* be digested warm in Spirit of Wine,

* The tinging Matter adhering to the Sticks and Gum is perhaps not a vegetable, but animal Substance; somewhat of the Nature of Cochineal, and deposited in Form of an Excrement, by a certain Kind of Bees, in the *Indies*. See a Paper upon this Subject in the *French Memoirs*; see also Mr. Boyle upon human Blood, *Abridgm.* Vol. II. p. 481.

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A red Rosin from red Saunders. the Menstruum acquires a deep red Colour; and if drawn off by Distillation, leaves behind it a red, tasteless, and inodorous *Rosin*, that affords no Smell even upon burning, nor dissolves in any expressed or essential Oil; yet, even in a small Proportion, tinges Spirit of Wine of a full red Colour, so as to render it useful for anatomical Injections, &c.

Another from Red Wine Lees. 50. In like Manner may a particular gummy, red Substance, or Pigment, be obtained, by Spirit of Wine, from dried red Wine Lees; and whether the tinging Parts of the more cumbersome dying Woods and Stuffs could not be advantageously extracted, at the Places of their Growth, so as to leave their ponderous Bulk behind, and bring away only their concentrated, essential Colours, might deserve the Consideration of the Merchant, the Dry-Salter, the Dyer, the Callico-Printer, &c. It might be tried in Log-Wood, Campeche, or Brazil; in Madder, Safflore, and many other dying Woods and Stuffs, whose Names we seldom meet with but in the *Bills of Entry*.

EXPERIMENT IV.

The Way of preparing an animal Colour called Prussian Blue.

The Process for making Prussian Blue. 51. Take of crude Tartar and Nitre, each four Ounces; pulverize, and mix them together; and, by Deflagration, bring them to a fixed Salt; which being powdered hot, add to it four Ounces of thoroughly dried Ox-Blood, reduced to fine Powder: Calcine the Mixture in a covered Crucible, whereof it may fill two thirds: Then lightly grind the Matter in a Mortar, and throw it hot into two Quarts of boiling

boiling Water; boil them together for half an Hour; afterwards strain off the Liquor, wash the black remaining Substance with fresh Water, and strain as before; continuing to do thus till the Water poured off becomes insipid. Put the several Liquors together, and evaporate them to two Quarts. Now dissolve an Ounce of green Vitriol, first calcined to Whiteness, in six Ounces of Rain-Water, and filtre the Solution. Dissolve also half a Pound of crude Allum in two Quarts of boiling Water; and add this to the Solution of Vitriol, taken hot from the Fire; pouring to them likewise the first Lixivium, whilst thoroughly hot, in a large Vessel: A great Ebullition and a green Colour will immediately ensue. Whilst this Ebullition continues, pour the Mixture out of one Vessel into another, and afterwards let it rest; then strain the Liquor thro' a Linen Cloth, and let the Matter, or Pigment, remain in the Strainer; from whence put it, with a wooden Spatula, into a small new Pot; pour upon it two or three Ounces of Spirit of Salt; and a beautiful blue Colour will immediately appear. Let the Matter be now well stirred; then suffered to rest for a Night; afterwards thoroughlyedulcorate it by repeated Affusions of Rain-Water; allowing a proper Time for the Precipitate to subside: And thus, at length, it will become exquisitely blue. Lastly, let it drain upon a Linen Strainer, and dry it gently: By all which Means it becomes the Pigment that goes by the Name of the *Prussian Blue*.

52. The Success of the Experiment depends greatly upon the Calcination. The Crucible is first to be surrounded with Coals, at some Distance; that it may grow gradually hot, and the Matter leisurely flame and glow. Let this

The Cautions required in it.

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Degree of Heat be continued till the Flame and Glowing decrease; then raise the Fire that the Matter may glow with an exceeding white Heat, and but little Flame appear above the Crucible. The Lixiviums should be very hot, and mixed together with the utmost Expedition*.

Its Nature. 53. The Method of making this *Prussian Blue* in Perfection, has been held and purchased as a very valuable Secret, both in *England*, *Germany*, and elsewhere; but it is now got into several Hands. Its Process is very extraordinary, and could scarce be deduced *a priori*, from any reasoning about the Nature of Colours. It is allowed an excellent blue Pigment, and by some preferred to *Ultramarine*; tho' its Durability might have been suspected, from the vegetable and animal Matters used in its Preparation, if the Colour did not seem wonderfully fixed by the Operation.

Many animal Matters used in Colours, 54. A great Variety of Colours are prepared by the Means of animal Matters; and more particularly by the Means of Urine; which, when it has stood to ferment, or putrify, serves to extract, change, or fix the natural Colours of some Bodies; and to heighten the Colours of others. Thus it is used in the preparation of the ordinary Blue called *Archil*; which chiefly comes to us from *Holland*: It is also used in the changing or fixing of *Turnsol*; so as to make a most elegant Red from the Sun-Flower: It is also a principal Ingredient, along with *Indigo*, in making that noble, fixed, and durable Blue, very lately discovered in *England*, for the staining of Callico; a Colour that first appears Green,

Particularly Urine.

* See *Philosophical Transactions*, N^o 381.

but

but by washing with Soap changes, and fixes into a lovely Blue.

55. Certain chemical Preparations from animal Subjects are likewise employed for extracting, changing, or heightening the Colours of various Bodies. Thus the alkaline, or volatile, Spirit of Urine, Blood, Bones, &c. extracts a fine Blue from Copper, changes a green Solution of Copper to a Purple, and heightens the Red of Cochineal. And doubtless the present Stock of Colours might be considerably enlarged, or improved, by a prudent Choice of animal Menstruums.

56. By animal Menstruums we mean both the natural and artificial Kind: The natural are such as Blood, Serum, Gall, Urine, Saliva, Rennet, Whey, Butter-milk, &c. most of which being properly employed, will either discharge or produce Colours. Thus recent Urine discharges the common Ink out of Linen; the Saliva discharges Red Ink; Butter-milk takes Stains and Mildews out of Linen, &c. Blood, we see by our present Experiment, affords a rich and beautiful Blue; and Gall is a natural Yellow; which may deserve to be treated as Blood, in making the Prussian Blue.

57. These natural animal Menstruums, or other animal Substances, being chemically treated, may afford a great Variety both of simple and compound Liquors, or new artificial Menstruums, for farther improving the Business of Colours, Dyes, and Stains. Thus, as putrified Urine affords an alkaline Spirit, by Distillation, that serves to produce, alter, or destroy a great Number of Colours; so likewise might the Liquors obtained, by Distillation, from recent, or fermented Whey, Butter-milk, &c. And by variously compounding these several Substances,

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or Liquors, even by random Trials, or chance Experiments, some new Discoveries in Colours might be made; as in the present Example of the *Prussian Blue*: Tho' we have a much greater Dependence upon Experiments conducted in a rational Manner; or in the Way of an Art, formed upon a competent Knowledge of chemical Operations, with their Productions and Effects; which will enable the Enquirer to reason, by Analogy, from one Experiment to another; and thus lead, in a sure and guarded Manner, to new Inventions and Discoveries.

The Experiment extended.

58. Thus, for Instance, the chemical Operator having found that common Bones, burnt only to Blackness, afford the Bone-black; it is easy to transfer the Experiment to Ivory, whereby a better Black is produced. And thus, upon finding that dried Ox-Blood has so great an Effect in making the *Prussian Blue*, we are naturally led to try the same Experiment with the Blood of different animals; or other concreted animal Juices, as Gall, Feathers, Flesh, Leather, &c. or the entire Bodies of certain Insects, Fish, Birds, &c. And this should be done with proper Diversifications of the Ingredients, and their Proportions; all along carefully noting the several Phænomena and Events; which will constantly afford Light and Instruction to the Mind, for the better regulating and conducting of the Enquiry, till it ends in a full Discovery.

EXPERIMENT V.

The Way of preparing a metalline Colour, from Gold and Tin, for tinging Glass of a beautiful Red.

59. Dissolve Gold in *Aqua Regia*, and dilute the fine yellow Solution with a large Proportion of

of fair Water; to the Mixture add, by Degrees, ^{The Ruby of Gold.} a sufficient Quantity of a saturated Solution of Tin, made also in *Aqua Regia*; and a most beautiful red, or purple coloured Powder will soon fall to the Bottom of the containing Glass. Decant the Liquor, and dry the Powder; a few Grains whereof being melted along with crystalline Glass, will tinge it throughout of an extremely fine purple or ruby Colour a).

60. By Means of this Experiment the ancient Art of Staining Glass red, long supposed to be ^{Its Uses, in the Art of Glass.} lost, seems at present restored. All the Colours are easily given to Glass, as we mentioned above b): But this seems to have been kept as a Secret in very few Hands, till lately; and may be considerably diversified, so as to introduce a grateful Variety of beautiful red and purple Colours in Glass c).

61. It should also seem that the Art of Callico-Printing, which now wants a Red, equally ^{In Callico-Printing.} perfect with the Blue it has lately obtained, might hence be furnished with such a Red; tho' there is Reason to suspect it might come out too dear for ordinary Use. But as the Perfection of this Art consists in discovering fixed, bright, and permanent Colours, not subject to change for the worse in the open Air; such Colours should rather be expected from mineral or metallic Matters, than from those of the vegetable and animal Kingdoms; which usually afford Subjects of too lax and alterable a Texture for permanent Colours, unless they could be some way substantially fixed.

a) See *Cassius de Auro*, p. 105.

b) See *Exp. II.* §. 15.

c) See Mr. Boyle's Philosophical Works. *Abridgm.* Vol. I. P. 457—459.

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*The Indian
Colours
how made.*

62. It appears highly probable that the *Indians*, for making the fine, bright, and durable Colours wherewith their Callicoes and Chintzes are stained, use metalline Solutions; for some stained Callicoes having been kept for forty or fifty Years, the bright Colours have been observed to eat out the Cloth, exactly in the same Manner as the corrosive, acid Spirits, which dissolve Metals, are found to do: Whence, to imitate their richest and noblest Colours, we are directed to use proper metalline Solutions, made after the Manner of our present Experiment.

*The highest
Improve-
ment of
Colours.*

63. But it would be a farther Step towards Perfection, not only in this Art, but also in the Art of Painting, to prepare the finest Colours without employing either acid or alkaline Salts; which usually subject Colours to change, or else are apt to prey upon the Cloth, or Canvas, as we see in Verdigrease, the blue and green Crystals of Copper, &c. Whence we are directed, (1) to search for Menstruums that are neither acid, alkaline, or saline; (2) for such metalline *Calxes*, Precipitates, or Powders, as will not lose their Colours by being well washed, to get out their Salts; (3) to prepare certain metalline Matters by Calcination, or the bare Assistance of the Fire; and (4) to look out for *native Colours*, wherein no saline Matter abounds.

*Variation
and Exten-
sion of the
Experi-
ment, by
Triture.*

64. (1) It may be worth the trying, whether certain Metals are not soluble by Triture, with the purest Oils employed in Painting, and such as contain neither acid nor alkaline Salts; or whether mere Water, the Whites of Eggs, Saliva, Gum-Water, &c. may not, by the same Means, be made to dissolve them; so as that the metalline Particles may be left behind upon Callicoes, Cloths, &c. when the aqueous or mucilaginous Matter is dried, or washed away from them.

them. But no great Effect can be rationally expected in such Attempts, unless the Triture be long continued, and Mills, or other well adapted Engines, be used for the Purpose: For we find, in all Instances, that Metals must be reduced to very fine Particles before they will tinge or colour.

65. (2) The Pigments or Colours obtained by Crystallization, such as the blue and green Vitriols, or Crystals of Copper, &c. cannot be deprived of their aqueous or saline Parts by a dry Air, or by Washing, without suffering extreme Alterations, or being left in the Form of a gross, terrestrial Matter, differently coloured from what they were at first. Thus the fine green Crystals of Iron, by being exposed to the Air, become white; and when well washed in Water, lose their Greenness, and turn to a reddish or yellow-coloured Ochre, or Earth: And if deprived of their saline and aqueous Parts, by a strong Distillation, they leave behind a brown or red *Caput mortuum*; which being washed in Water, affords not a green, but a dark-coloured Pigment, or Kind of *Spanish Brown*. And as this holds proportionably of other Colours obtained by Crystallization, there are little Hopes of procuring durable Pigments by that Operation, which shall be of the same Colours with the Crystals themselves; tho', after being well washed, different Colours may be thus procured.

66. (3) Metalline and mineral Matters are reducible to a considerable Degree of Subtlety or Smallness of Parts, by Fire, or dry Calcination; so as to leave them durably possessed of their native or adventitious Colours. Thus *Lapis Lazuli*, by being calcined, becomes the fine, durable, rich Blue, called *Ultramarine*: *Light Ochre*, by

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by the same Treatment, becomes a *light Red*; or the most useful Flesh-Colour in Painting. *a)* Lead, by Calcination, becomes durably red; and Iron, durably brown. But a proper Method seems wanting for the dry Calcination of the nobler Metals, Gold and Silver: Though, for the Uses of Gilding, &c. these nobler Metals are easily calcined by dipping linen Rags into their respective Solutions; then drying the Rags, and setting them on Fire, so as that they may burn to Ashes; whereby a dry and fine metalline Powder is readily obtained.

New and durable mineral Pigments discoverable.

67. (4) Many native mineral Pigments, or durably tinging Substances, are already discovered, that do not abound with Salts; such as Ochre, both yellow and red, Cinnabar, or Vermillion, Zaffora, Manganese, &c. and doubtless many others might be found in Countries that are stored with Mines, or where a proper Search is made after new mineral Substances *b)*.

Ores tried by the staining of Glass.

68.. Our present Experiment likewise affords an useful Method of examining Ores, or discovering a small Proportion of a metallic Substance in a large Proportion of Earth, &c. for a Quantity of pulverized crystalline Glass being ready at Hand, it is but mixing a little of the Ore, or mineral Matter, therewith, and melting them together; whereby the Glass will be deeply or lightly tinged of a certain Colour, according to the Nature and Quantity of the Metal contained in the mineral Matter. Thus a little Silver tinges white Glass yellow, Copper green, &c. Putty, or a Mixture of calcined Tin and Lead, turns it white, &c. tho' these Colours will somewhat vary, according to the Mixture of the metalline Matters with others, the Regulation of the Fire,

a) See above *Exp.* II. §. 20.

b) See *ib.*

and other Circumstances: So that a Sett of particular Experiments are required, to bring this Affair to greater Certainty, and reduce the whole to a regular *Table*. But this Method, if sufficiently verified, might be commodiously used, when the Quantity of Ore, or mineral Matter, is small, or contains but a very minute Proportion of Metal; for a little metalline Matter will thus tinge a large Proportion of Glafs.

69. The Art of Enamelling in Glafs also *The Art of Enamel-* depends upon a prudent Use of mineral Pig-*ling.*ments; or a Mixture of Miniature-Painting and Annealing: For the Method here is, to lay the Colours upon Glafs, as the Painter does upon Canvas; and afterwards to soften the Glafs, by a proper Degree of Heat, in the Annealing-Furnace, under a Muffle, till the Colours sink into the Glafs. And in this Manner also is Glafs frequently coloured, on its more superficial Parts, without being tinged throughout; as we see in the coloured Glafs of certain Church-Windows, and ancient Buildings.

AXIOMS and CANONS.

1. The preceding Enquiry shews, That the *physical Cause* of the Generation, Variation, and Destruction of Colours in Bodies, is the different Refrangibility and Reflexibility of the different Orders of the Rays of Light *a*).

2. That Colours therefore are not inherent in the Bodies said to be coloured; but rather in the Rays of Light which fall upon them; and are thence reflected to the Eye, so as to cause the *Sensation of Colour b*).

a) Exp. I. II.

b) Ib.

3. That

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3. That Colours, so far as they may be considered as in the Bodies said to be coloured, depend upon a certain mechanical Texture, or Mixture of the small Parts of Bodies; which Texture, or Mixture, being altered, or destroyed, the Colours also are altered, or abolished *a*).

4. That Whiteness in Light is an intimate Mixture of the several Orders of Rays; and Whiteness in Bodies, the actual Reflection of their Rays in their natural, mixed, or unseparated State *b*).

5. That Darkness is the Absence of the Rays of Light; and Blackness in Bodies, not a Colour, but the Want of those Rays being reflected from the Surface of the Bodies said to be black; or, in other Words, that Blackness is produced by the Rays of Light being absorbed, stifled, or drank in, by the Bodies denominated black *c*).

6. That *Transparency* in bodies is their Transmitting the Rays of Light; and *Opacity* their not Transmitting, but reflecting these rays *d*).

7. That common Light is compounded of seven different original orders of Rays; viz. Red, Orange, Yellow, Green, Blue, Indigo, and Violet; and that according as Bodies reflect more or less of these Rays, such Bodies appear of different simple or compound Colours *e*).

8. That great Alterations of Colours are producible by a bare Alteration of the Arrangement, Texture, or Mixture of the small Parts of Bodies; or by the Interposition of different Parts, upon bare Triture, and simple Mixture *f*).

9. That vegetable and animal Colours are, in general, less durable, or more subject to change,

a) Exp. I. II. *b*) ib. *c*) ib. *d*) ib. *e*) ib. *f*) Exp. II. III. IV. V.

than

than the mineral Kind; on Account of the looser, or more porous Nature and Texture of the two former, and the stronger and closer of the latter *a*).

10. That the Arts of Enamelling, and Imitating Precious Stones, in Glass, depend upon the Addition of metalline *Calxes* to the Glass of Lead, or pure crystalline Glass, in Fusion; and that an infinite Variety of the most durable and beautiful Colours are obtainable by this Means *b*).

11. That many new Colours may be reasonably expected from a proper Enquiry into, and a chemical Treatment of, various Subjects of the vegetable and animal Kingdoms *c*); and that there are four principal Ways of obtaining new, fixed, or durable mineral and metalline Colours; viz. (1) by discovering new *Menstruums*; (2) by finding such metalline Powders as will bear to be washed from their adhering Salts; (3) by properly applying dry Calcination; and (4) by enquiring after native mineral Colours that are not false *d*).

12. That a great Variety of new and fixed Colours may be prepared from Metals, and their *Menstruums*, or certain Mixtures of metalline and mineral Matters, for the farther Service and Improvement of the several Arts that depend upon Colours, Dyes, and Stains *e*).

a) Exp. II. III. IV. V. *b*) Exp. II. V. *c*) Exp. III. IV. *d*) Exp. V. *e*) Exp. II. III. IV. V.

LECTURE XV.

CONTAINING

*Attempts to illustrate and improve the
common Ways of preparing Remedies.*

*The Sub-
ject.*

1. **T**HE Business we are now entering upon is Pharmacy; a Subject which has almost engrossed Chemistry to itself: Whence many understand by Chemistry little more than the Preparation of Medicines. This Notion is countenanced by the Books of Chemistry generally published; which seldom contain more than Directions for the Making of Medicines: So likewise the Courses of Chemistry usually given, turn chiefly upon the Application of Chemistry to Pharmacy.

2. That Chemistry is applicable to the Illustration and Improvement of many other Arts, hath we hope been shewn in the preceding Lectures. But as the Application of it to Pharmacy is a Thing of Importance to Life and Health; and as Men generally think that this is the principal Office and Use of Chemistry; we judge it proper to bestow two Lectures upon the Subject: In the first whereof we propose to consider the present State of Pharmacy, with the Means to improve it, upon the footing it now stands; and in the second we will endeavour to shew how it may be reduced to a greater Degree of Simplicity; and thus be brought nearer to Perfection: The one we may call the *copious*, and the other the *concise* Method of Pharmacy.

3. We

3. We define *Pharmaceutical Chemistry*, the *Pharmaceutical Chemistry* Art of directing and performing the several Processes or Ways of Working, whereby natural Substances are reducible to useful Medicines.

4. And thus the whole Art consists of two Parts, a *Theory*, and a *Practice*: The Theory is claimed by the Physician, and the Practice is turned over to the Apothecary.

5. Most of the natural Bodies being some *History of* Way or other employed as Subjects of Pharmacy, *Pharmacy* the *Materia medica* is extremely large, and its Operations various. Its Materials in the earliest Ages indeed were few, and the Ways of managing them simple: Subjects afterwards multiplied, Operations increased, and at present we seem abundantly stocked with both simple and compound Medicines.

6. But the History of Pharmacy may deserve to be more particularly traced, in order to see by what Means it arrived at its present State, and how it may be farther advanced.

7. Diseases must have begun very early, if the first Inhabitants of the World experienced the same Changes of Seasons, breathed the same Kind of Air, and used a like Diet and Regimen of Life with ourselves. But soon after a Disease afflicts, the Patient seeks for a Remedy: Whence we may reasonably suppose that this was the Foundation of Pharmacy in various Parts of the World.

8. Experiments being thus multiplied, and the Event gradually introducing better Methods of preparing the Simples, Pharmacy would begin to appear in the form of an Art: Yet when *Hippocrates* came to compile a Kind of System of Physic from the Observations of Antiquity, he described but few Preparations, and those were generally simple.

Y

9. Suc-

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9. Succeeding Physicians enlarged the *Materia medica*: Galen considerably swelled the Catalogue, which received many Additions from the *Arabians*.

10. And when Learning began to revive in *Europe*, the *Materia medica* was again enlarged, and great Changes wrought upon it by Chemistry: Whence Chemistry at length was generally received, and acknowledged to be of use in Pharmacy.

11. Both the Galenic and Chemical Part of this Art are now extremely copious. Necessity gave the Occasion; Nature supplied the Materials; and Art and Observation discovered their Preparations, Virtues, and Uses.

12. Thus we at present seem provided with a Competency of standing Medicines; and have, by Degrees, acquired a Method of prescribing in *extemporaneous Forms*.

13. The Art of Pharmacy may be considered as under the Management of Physicians, Apothecaries, trading Chemists, and Druggists.

14. It is the Office of the Physician to direct the Medicines, or give Rules for extracting, compounding, and managing the Simples. If the Physician therefore should be defective in this Part, let the Apothecary, the trading Chemist, and the Druggist, be ever so just, or ever so knowing, the Art of Pharmacy must fall short of Perfection.

15. To the Apothecary belongs the Reduction of the *Materia medica* into certain Forms of Medicines, according to the Direction of the Physician.

16. But there are two Kinds of Apothecaries, vulgarly known by the Names of *wholesale* and *retail* Apothecaries. It is the latter alone we are here concerned with: These act by Rule,
gene-

generally follow their Standard, and compound with Art and Care; tho' they will sometimes substitute a *quid pro quo*, and now and then venture to reverse an Order. In Proportion to their Skill and Care they are more or less liable to be imposed on by the Druggist and the trading Chemist; all of them usually selling what they buy. But if the Apothecary be often deceived by them, how stands it with the Patient and Physician? or what is the State of Pharmacy?

17. The retail Apothecaries, however, deal more in *Substitution* than in *Sophistication*. The prudent Physician therefore prescribes what is usually kept, and proper to keep, in the Shops, or what is otherwise easily obtainable. If there are other Abuses committed in this Part of Pharmacy, they may perhaps be chiefly attributed to some Want of Skill or Conduct in the Physician.

18. The Design of the trading Chemists and Druggists is to furnish medicinal Matters to the Apothecary, who cannot always detect an artful Counterfeit, or a dexterous Sophistication: And perhaps many Remedies, well designed by the Physician, have failed, or had mischievous Effects, upon this Account.

19. This is proposed as a short Intimation of the present State of Pharmacy in *England*. If the Art be found more perfect in other Nations, it may perhaps be chiefly owing to this, That their Physicians are well acquainted not only with the Theory, but also with the Practice thereof; two Things which should never be separated, as being in Reality but one effective Thing consisting of two Parts; *viz.* previous Notion, and Execution.

20. What useful Addition or Reformation the *Materia medica* is capable of receiving, no one

at present can say. If a strict Enquiry were made, perhaps it might be found proper to throw out of our present Collection a considerable Number of Materials, to make Room for others of greater Efficacy. But this is no Work for private Persons. Our present Business is to see whether any Improvements may be made in the Ways of preparing the common Medicines of the Shops.

*Design of
Pharmacy.*

21. And for the better regulating of our Enquiry it may be of some Service to lay down two larger Observations; viz. (1) That the Design of Pharmacy is to separate from Bodies the more medicinal Parts with which they are naturally endowed; and, upon Occasion, to mix such of them together as will best answer the curative Intentions. All in the Power of Art is only to separate and mix, or differently modify; it is Nature alone that is able to produce. Pharmacy therefore consists in *Analysis* and *Synthesis* *.

Rules.

22. (2) As it is the Perfection of Art to copy Nature justly, so by resolving Bodies into their Principles we obtain a general Rule for Composition, and see the several Steps we ought to take in it. Nature shews us that in all mixed Bodies there is a Basis or *Substratum*; something to support and envelope the other Ingredients. Thus natural Salts are the diluted with Water; the Oils with both; and all together compose one uniform and elegant Whole. To prescribe justly, therefore, we should imitate Nature: If we compound without Regard to this Rule, the Ingredients will appear huddled together, as if it were by Chance; and,

* See *Lib.* VIII. and IX.

instead

instead of preserving and assisting, they will often clog, encumber, and destroy each other.

23. We now proceed to our Experiments, *The Intent by which we propose to illustrate and improve of the Experiments.* (1) the common Method of distilling Simple-Waters; (2) the common Method of preparing Tinctures; (3) the Method of preparing Syrups; (4) the Method of making Electuaries; and (5) the Method of making compound Oils, Unguents, and Plaisters: Thus proposing to touch upon the chief Articles of the present *Galenical Pharmacy*, as it is vulgarly called; tho' in Reality it be no less *chemical* than the other.

EXPERIMENT I.

The best Way of distilling Simple-Waters.

24. We took as much dried Mint, cut small, *Simple as filled two thirds of our Still; then adding a Waters, Quantity of Rain-Water sufficient to make the how distilled.* the Plant float commodiously, yet leaving a fourth of the Still empty, we digested a while with a gentle Heat; then worked the Still, drawing off only so long as the Water appeared thick or milky, and tasted rich and grateful; whereby we obtained a *Simple Mint-Water* in tolerable Perfection.

25. This Experiment, with a few occasional *The Experiment extended.* Alterations, may shew a general Method of obtaining Simple Waters in their greatest Perfection. The Subjects best fitted for it are those of the odorous, aromatic, and oily Kind; tho' some others also may perhaps communicate particular Virtues to the Water: Among the fittest may, however, be reckoned, *Angelica, Anniseed, Baulm, Calamint, Cinnamon, Cloves, Fennel, Hyssop, Rosemary, Tansey, Wormwood, &c.* but particularly

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cularly Pepper-Mint, which affords an extremely aromatic, pungent, and agreeable Water, good against the Cholic, and many other Disorders of the Stomach and Bowels; though its Use is, perhaps, too little known.

Cautions. 26. It is a principal Caution, in this Operation, to remove the Receiver before the more pellucid, acid, faint, and dead Water comes over, as it soon will do; and if suffered to mix among the rest it is apt to spoil the whole, by giving it a vappid or faint Taste, and sometimes a Degree of Acidity, or vitriolic Stypticity, and an emetic Quality; for Part of the essential Salt of the Plant, which now begins to rise, usually corrodes the Copper Head of the Still, and carries over with it some Particles of the Metal. Hence these Waters should be distilled either with a Glass Head, or one of Pewter, or well tinned Copper; or else the Operation should be carefully watched, that the second Running may not mix with the first. The greater Care should be taken, because some Patients, more particularly Children and those of a tender Habit, have suffered thro' a Neglect herein; and been vomited, purged, and griped by the Use of a Simple Water, contrary to the Intention.

Regulation. 27. The Simple Waters distilled after the Manner of our present Experiment may in many Cases prove too strong to be used alone; but then it is easy to let them down to the proper Strength with common distilled Water: And this is, beyond all Comparison, better than to mix such Waters with their own Faints, or Liquor of the second Running.

Improvements. 28. Two Improvements might be made in this Method of obtaining Simple Waters: The first, by means of Cohobation and Digestion; the other, by means of a previous

vious Fermentation of the Plant. With regard to the first; If the Liquor remaining in the Still be expressed from the Herb, and returned, along with all the Water that came over, upon a fresh Quantity of the same Subject, and they be digested together in a gentle Heat for two Days, and then distilled as before, the Water thus obtained will be much richer and more efficacious than the former: And if the same Process be repeated two or three Times, those who have not tried would scarce imagine how rich a Simple Water may be thus procured. This Method we would particularly recommend for making the Simple Water of Baulm, Elder-Flowers, Roses, Camomile, and such Subjects as are but sparingly furnished with essential Oils; for otherwise they make but indifferent Waters.

29. The other Means of improving Simple Waters is by using a previous, imperfect Fermentation; This is performed by adding to the Plant and Water, put together as in our present Experiment, a tenth or twelfth Part of Sugar or Honey, or else a fortieth Part of Yeast; then setting the whole in a warm Place to ferment for two or three Days only, so that the Herb may not fall to the Bottom, nor the Fermentation be above half finished: the whole being afterwards committed to the Still, a Water may, at one Operation, be obtained extremely rich, or impregnated with the full Virtue of the Plant. And thus may Simple Waters be made fit for long keeping without spoiling; the small Proportion of inflammable Spirit generated in the Fermentation serving excellently to preserve them. And these two Methods seem applicable to the Improvement of all those Simple Waters commonly found in the Shops.

30. We should next proceed to shew the Method of perfecting or improving Compound Waters, if we had not already endeavoured to do it in our *Lecture* upon Distillation by an Example in *Citron-Water* *.

EXPERIMENT II.

The best Way of making light Tinctures, and Infusions.

Light Tinctures prepared.

31. We took half an Ounce of the Rind of *Seville Orange* shaved thin, half a Dram of *Gentian Root* thin sliced, a Scruple of the Tops of *Roman Wormwood*, half a Dram of *Cardamums*, and half a Dram of *Cochineal*, each of them lightly bruised: These Ingredients we put to steep for a night in a Pint of *French Brandy*, and filtered the Liquor the next morning.

Regulation.

32. This Experiment is general, and not performed for its own Sake, but to shew the Method of making all Kinds of the lighter and finer Tinctures and Infusions without Fire, which would here prove prejudicial. The Preparation itself is, however, a good Stomachic Bitter, of the same general Nature with those commonly sold under the name of *Stoughton's Elixir*. The Excellence of these Preparations depends not more upon the Choice and Goodness of the Ingredients, than upon the Manner of their being infused: For if suffered to remain too long in the Menstruum, or if Heat be used in extracting the Tincture, the gross, terrestrial, and nauseous Parts of the Ingredients will be fetched out, and the Tincture thus be loaded with a heavy

* See *Leſt.* XIII. *Exp.* V.

inert Matter, of little Virtue. But if the Infusion be made in the Cold, and the Liquor strained off soon, only the finer and more spirituous Parts of the Ingredients will be imbibed by the Menstruum; whence the Preparation will not only taste and smell more brisk and agreeable, but also have a much greater Virtue and Efficacy. But if, thro' the Shortness of their Continuance in Infusion, the Ingredients should not have sufficiently impregnated the Liquor, the best Method is to pour it again upon fresh Ingredients, and again to strain it off, without letting it stay too long upon them, or applying the Heat of the Fire. And thus, by repeated Affusions of the same impregnated Menstruum upon fresh Ingredients, an Infusion or Tincture may be obtained, of almost any Degree of Strength or Richness, without containing the grosser or more inactive Parts of the Ingredients, but only what may be called their finer Spirit or Quintessence. And this is no inconsiderable Secret both in Chemistry and Pharmacy; and may deserve Regard of those who desire to procure the full Virtues of the Simples, unaltered in their Nature, yet exalted or concentrated to such a Degree, that a few Spoonfuls of the Liquor shall contain the Spirit or Quintessence of a Pound of a Plant. And this is an Effect not to be expected from the Fire, which almost constantly alters the Nature of Things committed to it; nor can a valuable Essence of Violets, Jasmin, Lilies, Borage-Flowers, or any Flower or Plant of an extremely fine odoriferous Spirit, be procured by Heat, tho' it readily may by steeping these Flowers in cold Water, cold Vinegar, cold Wine, or the like; and frequently pouring the Tincture upon fresh

fresh Flowers, till the Liquor becomes strongly impregnated.

33. Apothecaries usually commit the same Error in preparing the finer Tinctures, that they do in making their Cordial Waters; in both Cases saturating the Liquor with the grosser, more useless, and less spirituous Parts of the Ingredients; whence the Cordial Waters of the Shops too often abound with a gross, heavy, disagreeable Oil; and the Tinctures of the Shops with a gross, heavy Earth, or Kind of bituminous Matter, instead of a brisk, lively, and invigorating Spirit; which alone is the Thing required in both Cases.

34. This Doctrine of Tinctures and Infusions should be reduced to Rule for the Improvement of Chemistry, which will never be perfected till it can extract, separate, and concentrate, the Virtues of Things unimpaired, or unaltered in their Nature. And doubtless it would prove a very serviceable Thing in Chemistry, Medicine, and Natural Philosophy, to know the best and easiest Ways of concentrating the Virtues of Bodies unaltered: And this may, in some Measure, be effected by our present Method, and the Use of well adapted Menstruums: For, in general, (1) a quick and cold Infusion extracts the Spirit of Vegetables; but a long and hot one confounds, impairs, or destroys it. (2) To repeat quickly the cold Infusion of a fresh Subject in the same impregnated Menstruum, seems greatly to collect and concentrate the Spirit, that is, the finer and more essential Part of Bodies. (3) The proper Menstruums for this Purpose seem to be such as pure Rain-Water, Vinegar, Wine, Water mixed with a little fine Alcohol, Water and a little Sugar; and for certain Uses, the common atmospherical Air, which

which an excellent Menstruum to extract the Spirit or Effluvia of Plants, as we remarkably find in spicy Groves Gardens, and may be used with good Effect.

35. But to obtain the saturated Tinctures of hard, resinous, or gummy Bodies, requires a different Treatment, as in the following Experiment.

36. We took two Ounces of that hard *Indian* Solution of Rosin called *Gum Lac*, and reducing it into a *Gum Lac*. fine Powder, made it into a Kind of stiff Paste with Oil of Tartar *per deliquium*; we set this Paste in an open Glass to dry by a gentle Heat; then removed it to the open Air, that it might relent or grow soft; and after this we dried it again as before: By repeating the Process once or twice the hard Body of the Rosin was at length resolved into a purple-coloured Liquor; which being now gently dried, and reduced to Powder, afforded an excellent Tincture, by being boiled for two or three Hours in a tall Glass with Alcohol.

57. This Process is almost general, or may *The Experiment extended.* be advantageously used for making the Tinctures of *Myrrh*, *Gum Juniper*, *Dragons-Blood*, *Amber*, and other hard, gummy Substances, which will scarce otherwise yield a Tincture in Spirit of Wine. Any Improvement in the extracting Tinctures with Alcohol may tend considerably to improve the Art of Pharmacy; because such Tinctures are generally found powerful Medicines, the Spirit of Wine appearing greatly to increase the Virtue of the Subjects. Thus, tho' the Tincture of Amber prepared in this Manner appears to be only a bare Solution of the Substance of the Amber, yet it is found to have such Effects as are no Way equalled by any fine Powder of Amber: And what seems remarkable,

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able, tho' so large a Quantity of fixed Alkali be used in the Preparation of these Tinctures, yet they give no manifest Signs of containing an Alkali; which is therefore changed in the Operation, either by the Acid naturally contained in these resinous and gummy Bodies, or by being exposed to the Air, or by both.

Varied.

38. There are other Methods of extracting the Tinctures of these hard, gummy Bodies, but that delivered appears to be the best; tho' it might perhaps be shortened, by using some proper intermediate Substance to divide the Particles of the Subject, so as that the alkaline Salt, the Air, and the spirituous Menstruum might all come into fuller contact therewith and act more forcibly thereon. And for this Purpose we would recommend pure virgin Earth, such as is commonly used for the making of Tests or Cupels; by Means whereof Spirit of Wine will extract a tolerable Tincture from *Myrrh*, without the Addition of any fixed Alkali.

39. But when Tinctures not spirituous, or only aqueous Solutions of these hard, gummy Bodies are required, we recommend the Use of the soluble Tartar, or *Tartarum Tartarizatum*; for a Solution of this Salt will readily dissolve *Myrrh*, even in the Cold; as Water dissolves Gum-Arabic *.

EXPERIMENT III.

The best Method of making Syrups.

40. We took three Ounces of the yellow external Rind of fresh Oranges, and infused them in a close Vessel, with a gentle Heat in *Balneo*

* See *Lea* XIII. *Exp.* V. §. 47.

Maria,

Maria, for six Hours, along with a Pint and a Syrup of half of pure Water; then suffering the Infusion ^{Oranges} made. to cool we filtered the Liquor; and, adding to it twice its own Weight of hard double-refined Sugar, made it into a Syrup, in a close Vessel set in *Balneo Mariae*.

41. We could not contrive a general Example ^{Uses.} to fit all Syrups, because they differ greatly in Respect of the Liquors of which they are made; or according as these Liquors are Infusions, Decoctions, natural Juices, Wines, or Vinegars. We chose to give an Instance in a Syrup made of a Liquor by the Infusion of an aromatic Substance, whose Virtue would be almost intirely lost if the Syrup were to be prepared by long Boiling, as it is sometimes directed, with less than an equal Weight of Sugar. Dispensatory-Writers have perhaps no where erred more remarkably than in directing the Making of Syrups; which seems the more strange, because this Part of Pharmacy is extremely facile. The Misfortune seems to have lain here, that great Men cannot submit to consider common and ordinary Things: nevertheless the Credit of a Physician may sink in the Esteem of those who by their Employment are led to a Knowledge of these ordinary Things.

42. We judge that the Whole of this Business may be reduced to a few easy Rules, which we shall here endeavour to lay down for improving this Branch of Pharmacy. And (1) It is Mat- ^{Rules.} ter of Experience that aqueous Infusions, Decoctions, or other aqueous Liquors, require twice their own Weight of dry Sugar-Candy to make them into a Syrup of a just Consistence for keeping, without candying or fermenting. This Rule, by directing the Use of *Sugar-Candy*, seems to fix the Consistence of Syrups with Exactness;

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ness; because all Salts acquire a determinate Proportion of Water in crystallizing; so that Sugar in the Form of Candy consists of one certain Proportion of Water, whilst different Kinds may hold more or less aqueous Matter, according to the Manner of refining, the Accidents of Weather, &c. Hence therefore all such Infusions for Syrups as are of a delicate or destructible Colour, which is impaired by boiling (for Example, Violets, Clove-July-Flowers, &c.) and all such Infusions as contain any volatile Parts, which would evaporate by a boiling Heat, (for Example, those of Nutmeg, Cinnamon, Orange-Peel, Citron-Peel, &c.) should have twice their own Weight of Sugar added to them, and be kept close covered in the gentle Heat of a *Balneum Marie*, till the Sugar is dissolved; to hasten which the Sugar should be first reduced to fine Powder.

43. (2) The Decoctions of such vegetable Substances as lose no valuable Parts by boiling, may be boiled down to the Form of a Syrup along with their own Weight of Sugar; the two being first clarified together with Whites of Eggs in the ordinary Way: But if the Ingredients here contain any unctuous or balsamic Parts on which their medicinal Virtues depend, let the Sugar be added from the first, and boiled along with the Ingredients; afterwards straining and clarifying the Decoction, before it is boiled to near the full Consistence of a Syrup. This Rule is founded upon that remarkable Property which Sugar has to dissolve Oils, or the finer resinous Substances, so as to make them intimately mix with Water. Whence it may deserve to be considered whether the Syrup of *Myrtles*, *Comfrey*, and *Diacodium* should not be thus prepared. It must also be observed that
by

by boiling the Sugar so long with the Decoction the aqueous Part exhales, and leaves the Syrup much stronger than it could have been made without this boiling.

44. (3) All vegetable Juices are to be thoroughly purified before they are made into Syrups. Thus the Juices of Citrons, Lemons, and Oranges are to pass the Filtre, and then be made into Syrups, without boiling, according to the first Rule; observing to use no metalline Vessel about them. But the Juices of Fruits, as particularly Mulberries, Rasberries, &c. will not clarify without a beginning Fermentation; but by standing for a Day or two they will begin to ferment and liquify, and may then be commodiously strained thro' Flannel; after which these also are to be made into Syrups with about an eighth Part less than twice their own Quantity of Sugar, or with two Pounds and twelve Ounces of Sugar to a Pint of Juice, on account of their being somewhat saccharine themselves. And this holds also of Wines and Vinegars, when they come to be made into Syrups; for Wine contains an inflammable Spirit which does not incorporate with Sugar; and also a thick syrupy Substance, which is found in Vinegar likewise. By a due Application of these Rules we apprehend the Business of making Syrups may be brought to tolerable Perfection.

EXPERIMENT IV.

The best Method of making Eleſtuaries, by an Example in the Sassafras-Eleſtuary.

45. We took two Ounces of the best Sassafras The Sassa-
newly rasped, and half an Ounce of Cinnamon fras Elec-
finely powdered; these Ingredients we boiled in tuary made
a tall

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a tall Glass in a Sand-Heat, with ten Ounces of Water and fourteen Ounces of Sugar, so as that nothing might evaporate, for two Hours; then straining and pressing out the Syrup, we added to it an Ounce of fresh rasped Sassafras, a Dram of Cinnamon, and ten Grains of Nutmeg, both reduced to fine Powder; and made the Whole into an Electuary.

Regulation.

46. In the common Method of making this Electuary the Sassafras and Cinnamon are boiled in the Water, whereby a great Part of their Virtue is lost or not extracted: Whence the Medicine comes to be defrauded of its Due. But here, by boiling the Ingredients in a tall Glass, with a due Proportion of Sugar and Water, to make a Syrup (allowing an extraordinary Proportion of Water for what the Sassafras will drink up) we obtain the fine aromatic Virtues of the Ingredients to Advantage, without any considerable Loss.

Rules.

47. To make Electuaries in Perfection where a Syrup is employed as their Basis, (1) the Syrup should be prepared in the Manner above delivered *, so as that the Virtues of the Ingredients may be preserved; (2) the Powders, or Species employed, should be fresh and fine ground; (3) the Gums, where any are used, must be well cleansed, and dissolved in their proper Menstruums; and (4) the Whole must be mixed, or thoroughly united, into a smooth, uniform Substance, of a due Consistence for keeping, without either candying or running into Fermentation.

48. (1) Where Syrups are used in the making of Electuaries, care is not only required that the Virtues of the Ingredients of the Syrups be

* *Exp. III.*

preserved as much as the Form will allow of, but also that its Consistence be not too high ; for this would dispose it to candy in the Electuary, and render the Medicine unduly mixed, or knotty ; the Sugar concreting together in Lumps, or shooting away from the Species. Again ; If the Syrup be made too thin or aqueous, so as not to suspend and hold the Powders together by a binding Consistence, it will of Necessity ferment in hot Weather, and become first somewhat vinous, afterwards sour or acetous, and at length corruptive *a*) ; so as to change, invert, or destroy the Nature of the Medicine : For purgative Ingredients, by Fermenting, lose their purgative Virtues ; and all other Ingredients, by Corrupting, are reduced to an inert Kind of Fæces or *Caput mortuum*, very different from the Thing intended *b*). And hence Electuaries that have thus fermented, or changed their Nature, may sometimes prove pernicious, instead of salutary.

49. The Electuaries made with the Pulp of Fruits are less disposed to keep, for any considerable Time, perfect, on account of the greater Tendency which such pulpy Substances have to Fermentation and Putrefaction. Thus, tho' the *Lenitive Electuary* were made ever so artificially, it will scarce keep many Months without altering its Nature ; but especially if the Consistence was originally too thin : Whence such Electuaries should be made in small Quantities, or fresh as they come to be wanted.

50. But this does not equally hold of the *capital Electuaries*, such as *Venice-Treacle*, or *Mithridate* ; which require to lie for some Time, that the Ingredients may digest, or ripen, as it were,

a) See *Lect. X. passim.*

b) See *Lect. VII.*

and grow mellow together; for the Gums and Spices that enter these Compositions preserve the Medicines from Alterations for the worse, and the Mixture becomes more perfect by Time; provided the Honey used in their Composition do not candy, or the Whole become too dry. To keep the Honey from candying, some Artifts mix the Spices and Gums with it unclarified; only taking Care to separate the foul Parts that lodge either at the Top or Bottom. And if the Medicines prove too dry, it is usual at any Time to soften, or beat them up in a Mortar, with *Canary*: And thus these Capitals of the Shops are supposed to improve by keeping. But *Diascordium*, having few of the warm Gums in its Composition, is more apt to alter, and lose of its astringent or styptic Quality by keeping: For which Reason it seems an Alteration here for the better, to use a Quantity of *Saccharum rosatum* instead of Honey, or *Diascordium*; as this not only gives a greater Compactness to the Medicine, but also contributes to preserve its Colour and Virtues.

51. (2) The Powders, or Species, that enter the Composition of Electuaries, should be fresh, because they lose of their Virtue by keeping; and they should also be fine ground, because they would not otherwise intimately mix with the Honey or Syrup, nor so readily part with their Virtues in the Stomach, nor render the Medicine so agreeable to the Eye. The common Method of reducing these Powders to a sufficient Degree of Fineness, by the Mortar and Searce, is faulty; because this Method exposes them too long to the Action of the open Air; whereby their more volatile and grateful Parts are carried off, whilst only the grosser are left behind: it might therefore be proper to have a close Engine

Engine contrived for the Purpose, so as to prevent this ill Effect.

52. Some Artists grind their Powders for *Improve-*
Electuaries by Means of a Horse-Mill; but the *ments.*
Mill-Stones here wear off, and communicate a
gritty or stony Matter to the Ingredients, so as
to prove disagreeable in the Mouth, and some-
what increase the Bulk of the Medicine, with-
out adding to its Virtues. Nor is this Method,
by the Mill, free from the Inconvenience of the
Mortar; for the finer or more spirituous Parts
of the Ingredients also fly off; as is sensibly found
by the whole Neighbourhood where any large
Quantity of the Ingredients for *Venice-Treacle*,
&c. is ground by the common Horse-Mill.

53. (3) The better Way doubtless is, by the
Means of Iron Rollers, moving opposite to each
other in a close Box, to grind all the Ingredi-
ents, *viz.* the purified Gums, the Roots, Herbs,
Flowers, &c. along with the Honey and Wine,
after the Manner of the new-invented *Chocolate-*
Engine; for thus the fine, volatile, and aromatic
Parts of the Ingredients may, as well as the
grosser, been tangled with the Honey and Gums,
and all at once be mixed uniformly together in-
to a smooth Mass of a due Consistence.

54. (4) But perhaps a much better, though
more troublesome, Method would be, to get
out the full Virtues of the Ingredients, without
any of their grosser Parts, in the Form of Ex-
tracts, essential Oils, &c. and to mix these Oils,
Extracts, Gums, Rosins, &c. together, with a
suitable Proportion of Honey, &c. so as at once
to perfect and concentrate the Medicine; which
might therefore be given in Doses of an agree-
able Smallness, with all the Advantages that can
well be expected. And the same Method seems
also applicable to the making of *Pills* and *Troches*.

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EXPERIMENT V.

The best Methods of making the compound Oils, Unguents, Cerates, and Plaisters.

Oils, or Liquid Balsams.

55. We took twelve Ounces of fine Sallad-Oil, half a Pint of *Canary*-Wine, and half an Ounce of Dragons-Blood reduced to fine Powder; these we boiled together, over a gentle Fire, till the Wine was exhale; and thus obtained a fine red Oil, or liquid Balsam. (2) To

Consistent Balsams.

one Half of this Oil we added four Ounces of yellow Bees-Wax, six Ounces of *Venice* Turpentine, and dissolved them together over the Fire; then removing the Vessel into the Cold, we added half an Ounce of Balsam *Peru*; and thus made a red Ungent, or better Sort of *Lucatellus's* Bal-

Cerates.

fam. (3) To the other Half of the red Oil we added a due Proportion of Wax; so as when cold to give it the Consistence of a Cerate, or soft Plaister: And (4) By adding more Wax, and a Proportion of Rosin, we made the Cerate into a Plaister of a hard Consistence.

Plaisters.

The Experiment extended.

56. This Experiment at once shews us the Method of preparing the compound Oils, Unguents, Cerates, and Plaisters. The making of compound Oils, in general, depends upon boiling certain Ingredients, as particularly recent Herbs well bruised, or else their Juices, in Oil, till the aqueous Moisture is exhale (as the Wine was in the present Experiment) and the Plant become almost crisp; at which Time the Vessel must be removed from the Fire, and the Oil squeezed from the Herb by Means of a Screw-Press.

And applied.

57. This Oil is now to be set over the Fire again, that its remaining aqueous Moisture may exhale,

exhale, and the grosser Parts of the Whole subside; whereby the Oil will become not only more beautiful in Colour, but also more durable, or keep the better from turning mouldy. If the Pan be not removed from the Fire before the Herb is grown crisp, the Oil will be in Danger of turning black, or being burnt; which both spoils the Colour, and gives a disagreeable Odour. If these Cautions are duly observed, the common compound Oils, by Decoction, may be obtained in their intended Perfection; as Oil of Camomile, Elder, Roses, Earth-Worms, &c. And after the same Manner are several compound Ointments made, by boiling Herbs along with Lard, or Suet; as the Ointment of Elder, Populeon, Nerve-Ointment, Melilot-Suet, &c.

58. The red Oil, obtained in the first Step of our present Experiment, shews how liquid compound Balsams are procurable by dissolving resinous Gums in Oil, over the Fire. And in this Manner a fine Balsam may be made with *Gum Elemi*, and tinged beautifully red with Dragons-Blood, or an Infusion of Alkanet-Root in Oil. And upon the same Foundation might several excellent liquid Balsams be prepared for chirurgical Uses.

59. Powder of Red Saunders has been commonly used, instead of Dragons-Blood, in the making of *Lucatellus's* Balsam; but doubtless Dragons-Blood is much better suited to the Intention of a Balsamic, a Healer, and Detergent; and also improves the Colour of the Medicine: Tho' Red Saunders may be made to give a very good red Colour to the Balsam, by infusing the Powder cold for two or three Days in White Wine; which opens the Body thereof, exalts the Colour, and renders it communicable with Advantage to the unctuous Ingredients.

But this End may be more expeditiously answered by infusing a little Alkanet-Root in the Oil.

60. The Consistence of an Unguent is given either by using animal Fats, as Lard and Suet, or by the Addition of Wax, Rosin, Pitch, dry Powders, metalline *Calces*, &c. and by adding a smaller or larger Proportion of these solid or dry Ingredients, we obtain the Consistence of a Cerate, or Plaister, respectively. When hard animal Fats are used, the Process differs not from that for making the compound Oils*; and where Wax, Rosin, &c. are employed, the Management is the same as in the present Experiment, where the Consistence of the Oil is thickened into that of a Balsam by Wax.

61. When dry Powders, or metalline *Calces*, are used in the making of Ointments, the Powders should be fresh and fine ground, and the metalline *Calces* made more subtile by Triture; after which the Whole may be mixed smooth together, or beat up in a Mortar: And thus the *Unguentum album*, *Desiccativum rubrum*, *Diapompholyges*, &c. are readily prepared.

62. The Plaisters made with metalline *Calces*, such as *Diachylon*, and *de Minio*, require no Wax or Rosin to give them an emplastic Consistence; the bare Solution of the metalline *Calces*, or the Litharge, and Red Lead, by boiling in the Oil, being sufficient for the Purpose. Thus, if half a Pound of Red Lead, half a Pint of Vinegar or Water, and twelve Ounces of Oil, be boiled together over a gentle Fire, with continual Stirring, till the aqueous Moisture be consumed, and the Red Lead entirely dissolved; the Matter, when cold, will be of a hard, emplastic Consistence, and differently coloured, or red,

* See above §. 55.

brown,

brown, or black, according as it was more or less boiled.

63. In the making of Plaisters with metalline Powders and Oils, it is always proper to add Water or other aqueous Liquor, to keep the Mixture from burning, or turning black, before the due Consistence is gained, or the requisite Dissolution made. But here great Care must be had, not to throw in cold Water, if that added at first be exhaled before the Operation is finished; for this would be dangerous, by causing the Matter to crackle, fly about, and boil over with great Violence: But if the Water be added in the State of boiling, it occasions no Tumult; and may be thus used with Safety.

64. When aromatic Species, native Balsams, or essential Oils, are ordered in Unguents or Plaisters, Care must be taken to add such Ingredients towards the End of the Operation, when the Vessel is removed from the Fire; because the Heat of boiling Oil, &c. would cause the fine aromatic or odoriferous Parts of the Ingredients to exhale, and be lost to the Unguent or Plaister. The same Caution should be likewise extended to the *Cantharides* used in the *Pasta epispastica*, &c. and to other Bodies of a delicate Texture, whose more efficacious Parts are exhaled by Heat. And by the due Observation of these few Rules and Cautions, the common compound Oils, Unguents, Cerates, and Plaisters, may be made in considerable Perfection.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, That some Part of the Salts of Plants, as well as their Oils, will rise by Distillation with Water, and give an acid or alkaline Nature to the

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simple Waters thus prepared, according to the Nature of the Plant *a*).

2. That no Simple Waters should be distilled so low, as to bring over any remarkable acid or alkaline Liquor from the Plant; for fear of mischievous Effects, or making such Waters prove emetic or purgative, contrary to the Intention *b*).

3. That the Virtues of Simple Waters chiefly depend upon their containing the essential Oil of the Plant *c*).

4. That there are two Methods of perfecting Simple Waters; *viz.* Cohobation, and Fermentation *d*).

5. That all Tinctures and Infusions of Ingredients, whose principal Virtues depend upon their lighter, or more subtile and spirituous, Parts, should not be made with Heat, but in the Cold *e*).

6. That if such Tinctures or Infusions be required rich and strong, they are to be made so, not by suffering the Menstruum to remain long upon the Ingredients, or by the Use of Heat; but by adding fresh Ingredients several Times to the same Liquor; infusing them quick, and each Time keeping out the Ingredients that have once been used *f*).

7. That the Fire is apt to exhale, alter, or consume the more subtile and spirituous Parts of Vegetables; and therefore unfit to be used where these more delicate Parts are required *g*).

8. That the Business of Infusions and Tinctures may be greatly improved by extracting the efficacious, or more spirituous Parts of Vegetables, unaltered in their Nature; yet con-

a) Exp. I. *b*) ib. *c*) ib. *d*) ib. *e*) Exp. II.
f) ib. *g*) ib.

centrated,

centrated, or brought together into a moderate compass.

9. That rich Tinctures may be extracted, with Spirit of Wine, from the hardest resinous and gummy Bodies hitherto known, by Means of fixed Alkali properly applied *a*).¹

10. That even aqueous Solutions may be made of the same Kind of Bodies, by Means of the *Tartarum tartarizatum*, or soluble Tartar *b*).

11. That the Ways in common Use for the making of Syrups, Electuaries, compound Oils, and Plaisters, are improveable by the Observance of a few easy Rules *c*).

12. That, therefore, there are grounds to expect some Improvement of the common Pharmacy, upon the footing it now stands, barely by perfecting the Methods of preparing the Shop-Medicines in Use, without either retrenching their Number, or introducing new ones; that is, by reducing the Art to a greater Simplicity.

a) Exp. II. *b*) ib. *c*) Exp. III. IV. V.

LECTURE XVI.

CONTAINING

Attempts for reducing PHARMACY to a greater degree of Simplicity and Efficacy.

The Subject.

WE now proceed to consider how Pharmacy may be reduced to Simplicity; which in Arts appears to include Perfection.

The Simplicity of Pharmacy.

2. The Simplicity of Pharmacy seems to consist in supplying a few powerful, parable, safe, and agreeable Medicines, for the Cure of Diseases.

The Fate of Medicines.

3. Those versed in the History of Physic observe that Remedies have their Run, or Revolutions of Fate and Fortune; many of them being highly esteemed or magnified for a Season, and afterwards thrown aside and neglected.

4. Not to mention the Medicines celebrated by the Ancients, there are Numbers of others which have had their Revolutions almost within our own Memory. The *Elixir Proprietatis* of Paracelsus, the *Liquid Laudanum* of Helmont, the *Sal volatile oleosum* of Sylvius, the *Aperitive Tincture* of Mæbius *, the *Antibellie* of Poterius, the *Aqua benedicta*, or *Vinum emeticum*, of Rulandus, the *Bezoardic Powder* of Sennertus, Ceruse of Antimony, and many more, have been extrava-

* That is, Spirit of common Salt neutralized with Salt of Tartar, and tinged with Red Roses.

gantly

gantly valued in their Time; but are now sunk in the Esteem of Physicians. And thus perhaps our present Opiates, our Salt of Vipers, our Pearls, our Bezoar, our *Aurum fulminans*, &c. may lose their Credit hereafter, or give Way to others of no greater Efficacy.

5. If we enquire into the Cause of this Instability in Pharmacy, it does not appear owing to the Medicines themselves, but rather to the Inattention, Levity, and Rashness of Men: Inattention, in not sufficiently regarding and distinguishing between the Kinds and Differences of Distempers and Constitutions; Levity, in presently changing one Medicine for another, if the expected Effect is not soon procured; and Rashness, in using such Medicines as come recommended by incompetent Judges, or unfair Representers. *Cause of their Fate.*

6. If the Cause were owing to any Changes in the Medicines themselves, we could have little Hopes of redressing the Evil; but as it is owing to ourselves, we are hence encouraged to look out for a Remedy.

7. The Art of forming a sound Judgment of the Success and Virtues of Medicines is so little known, that the Mind usually fluctuates therein, as being destitute of a secure Foundation; and consequently is led by Rumour, Opinion, and Example, instead of the true Light arising from careful Observation, and well digested Experience. Whence it frequently happens that unlucky Events are attributed to useful Medicines; whilst such Events were really owing to some other Cause. *Regulation.*

8. This Inattention is succeeded by Levity and Rashness: For when a Medicine thus fails to answer the Expectation conceived of it, it is usual to reject it with Contempt, and immediately to seize

seize, in its Stead, the first new one that comes strongly and vehemently recommended; which again, after Trial, is frequently rejected in the same Manner as the former. And thus the Lives of Physicians are often spent in flying from one Medicine to another, without fixing upon those that are stable, or such whose Virtues are duly determined and ascertained.

9. This perverse Temper or ill Habit of the Mind must therefore be cured; or else Physicians will continue to fluctuate, and never bring Pharmacy to a State of Perfection.

10. The Way of rectifying this ill Habit, we apprehend, is to acquire a Competency of sound and fundamental medicinal Knowledge, by keeping steady to the Use of a few simple Medicines; which are easily prepared, no way hazardous, and yet powerful in their Effects: And to shew the Way of procuring a few such Medicines, is the Design of our present Lecture.

11. We judge that all Medicines are commodiously reducible to four general Classes; viz. *Evacuants, Alterants, Strengtheners, and Quieters*: For as all the Causes of Diseases must regard either *Quantity, Quality, or Motion*, the Medicines adapted to these Causes will be either *Evacuants, Alterants, Augmenters, or Appeasers* of Motion in the Body.

12. It must, however, be observed, that under each of these general Tribes of Medicines there are some better adapted than others to the Diseases of particular Parts. Thus it is Matter of Observation, that Mercury particularly affects the salival Glands, Cantharides the Bladder, &c. all which Remedies are to be collected, as so many particular Instances, under our respective general Heads of Medicines. And by duly proceeding in this Manner, it should seem that

we

we might easily fix upon a small Collection of Remedies, able, with a proper Regimen, to cure the ordinary Diseases.

13. At least, by throwing out of our present Collection such as are certainly found to be of small Efficacy, or certainly dangerous, we might greatly retrench the present Set of *Officinals*, and bring the more serviceable of them within the Compass of a *portable Chest*. And with this View we shall endeavour to point out some of the more efficacious, parable, safe, and agreeable Evacuants, Alterants, Strengtheners, and Quieters; all along fixing a Mark upon those which we take to be either unsafe or insignificant.

14. Our first Experiment will shew a Method of procuring a safe Emetic; the second will shew how to prepare a safe Purgative; the third how to prepare a safe Perspirative; the fourth how to prepare a safe Alterant; the fifth how to prepare an innocent Strengtheners; and the sixth how to obtain a powerful Quieter, or Anodyne.

EXPERIMENT I.

An easy and simple Method of obtaining a safe and gentle Emetic.

15. Two Drams of the common white Ipeca- *An Emetic*
cuanha being reduced to fine Powder, and infu- *prepared.*
sed for two or three Days in half a Pint of white
Lisbon Wine, in the Cold; if the clear Liquor
be decanted, fresh Wine may be added to the
remaining Powder, so as to extract all the Vir-
tue, which it will thus yield to Wine in the Cold.

16. This Infusion of Ipecacuanha in Wine ap- *Uss.*
pears to be the most safe, gentle, and agreeable
Emetic hitherto known: Whence it may in most
Cases be properly substituted for the *Vinum bene-*
dictum

diſtum, the *Tartarum emeticum*, and the other antimonial Emetics ; which are all attended with ſome Degree of Virulency and Uncertainty in their Operation.

*Ipecacuan-
ba analysed*

17. The Ipecacuanha Root, upon a proper Analysis by Means of Water and Spirit of Wine, is found to contain a direct ſaline and refinous Part, whereof the ſaline is the larger ; whence even an aqueous Infuſion of the Root will largely extract its Virtues : So that a ſtrong White Wine ſeems a Menſtrum well adapted to the Extraction both of its ſaline and refinous Parts, on account of the large Proportion of Water, and a leſs of inflammable Spirit, that it contains. Add to this, that Emetics, as well as Purgatives, are found to act the freer, eaſier, and quicker, when joined with Wine, or other ſtrengthening ſpirituous Vehicle. However, after both Water and Spirit of Wine have ſucceſſively acted upon this Powder, it ſtill retains ſome Virtue ; ſo that its Power is greateſt when given in Subſtance : Whence our preſent Method of extracting a Tincture from it with Wine only abates its Violence, and, in ſome Meaſure, moderates its Operation ; ſo as to fit it for weak Conſtitutions, or render it almoſt univerſally ſafe.

*Not improved by
Chemistry.*

18. This Root may, therefore, paſs for one of thoſe Simples which are little or nothing improved by a chemical Treatment ; Nature ſupplying it almoſt ready prepared to our Hands, ſo as to require no more than drying and Reduction to Powder, at moſt no more than a bare Infuſion in Wine, to render it a ſafe Emetic.

*Farther
Uſes.*

19. Now, being once poſſeſſed of ſuch an Emetic as this, which ſeems to include the Excellencies of all thoſe of the ſame Tribe, it is doubtleſs proper to praктиſe the *Method of Rejection*

tion upon the rest; or at least to examine whether any of them deserve to be retained and kept in the Shops.

20. We observed above *, that the common *Poisonous* antimonial Emetics, of which there is a great *Emetics.* Variety, are virulent, or in some Degree poisonous; and therefore not to be trusted, when safer can be procured to answer the End. 'Tis true, some Practitioners have ventured to give Arsenic itself, in the Quantity of a few Grains, as an Emetic; and thus it sometimes operates violently, after the Manner of the emetic Preparations of Antimony, which are nearly allied thereto. But as we certainly know, by many fatal Instances, that Arsenic is a virulent Poison, even in a small Dose; it may seem a Kind of Madness to use it as an Emetic, when Ipecacuanha is at Hand. And the same is to be understood, tho' in a less Degree, of the *Mercurius Vitæ*, Glass of Antimony, Antimonial Cups, the Perpetual Pills, the Sulphurs of Antimony, and indeed all other drastic Emetics; which have a direct virulent Virtue, and, if given in too large a Dose, produce poisonous Effects. And here we do not except *emetic Tartar* itself; which, unless prudently diluted with Wine or some Cordial Water, is apt to prove not only uncertain and churlish in its Operation, but sometimes virulent or poisonous; especially when exhibited in a dry Form, as in that of Pills, Powder, or Bolus: For all antimonial or other metalline Emetics, coming in a dry Form into the Stomach, seem to lodge in its membranous Coats, and stimulate and corrode them; so as to occasion Spasms, Convulsions, &c. after the Manner of Poisons.

* §. 16.

Regulation.

21. And tho' Solutions of Vitriol, Verdigrase, and various Preparations of Copper, have been, and still continue to be, used as Emetics, and generally operate quick; yet we cannot judge such Preparations safe, or any way comparable to Ipecacuanha for Safety. And even these cupreous Emetics, when given in a large Dose, have a corrosive Effect upon the membranous Parts of the Stomach; so as to prove, in a less Degree, poisonous. And thus, if the whole Tribe of Emetics were carefully examined, and their Effects noted from competent Experience, we judge they would most of them be found unsafe or dangerous; and consequently deserve to be banished the Shops, as Emetics, whilst their Place may be so well supplied by Ipecacuanha. And this Method of Examination and Rejection being duly practised, might, as we apprehend, thin our Shops, and reduce the Bulk of our Pharmacopœias, to the great Advantage of Pharmacy and Medicine.

EXPERIMENT II.

An easy Method of procuring a safe and effectual Purgative.

A Cathartic prepared.

22. If in a Quart of *Dulwich*-Water we dissolve an Ounce of fine Manna, and half an Ounce of black Tamarinds, then strain off the Liquor clear, we shall obtain an agreeable purging Ptisan, or cathartic Liquor, in a Dose sufficient for a full-grown Person of an ordinary Constitution; the Whole being drank at several Draughts, in the Space of about an Hour and half, or two Hours.

23. It appears to be Matter of Observation, that the common purging mineral Waters operate with

with more Ease, Gentleness, and Safety, than almost any Cathartics of the Shops; and only require to be concentrated by boiling, or quickened, in some Cases, to prevent the Trouble of taking two or three Quarts for a Dose. Our present Experiment, therefore, shews the Method of quickening these Waters, by the Addition of innocent Purgatives; such as are *Manna, Tamarinds, Epsom-Salt, Tartarum tartarizatum, Tartarum vitriolatum, &c.*

24. The Shops and common Dispensatories abound with purgative^d Medicines, many of them drastic, or violent, and some of them virulent, or almost poisonous; of which Kinds we reckon *Rosin of Jalap, Elaterium, Scammony, Gamboge, Coloquintida, Asarum, &c.* all which are of a caustic Nature, when given crude and alone, so as to prove mortal in a large Dose: Whence we apprehend that the crude and separate Use of all such Purgatives should be banished; especially as there are numerous Instances of their deleterious and poisonous Effects, and as we are abundantly provided of safer and more gentle Kinds; for Example, *Rhubarb, Manna, Tamarinds, Cassia, Cremor Tartari, Epsom-Salt*; and particularly the purging *mineral Waters*. Or if the Use of the more violent purging Simples be still retained, let them at least be boiled in Water; which is a certain way of rendering them milder, and discharging a great Part of their Malignity. And for the purgative Rosins, particularly those of *Jalap* and *Scammony*, we would recommend them to be ground fine, and beat into a Paste, with twice or thrice their Quantity of blanched Almonds; which, by their oily Matter, dissolve the Texture of these Rosins, and render them more safe and innocent *.

* See below Exp. III.

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25. But we do not apprehend that the Art of Medicine has any Occasion for those violent Purgatives. Certainly violent Purgatives are seldom proper, and generally prejudicial. If the stronger be ever required, we would, instead of the former virulent Kind, recommend the simple Powder of Jalap-Root; which is found to operate much more mildly, and with greater Certainty and Effect, than its Resin, Tincture, or other chemical Preparations of the Root; which is also the Case of *Mecchoacan* and *Rhubarb*.

26. We desire it may be remembered, that the deleterious or poisonous Nature of the violent Purgatives above mentioned is much greater in the Body than that of the poisonous Emetics; doubtless because some Part of these Emetics is soon thrown up again by the Stomach; whereas the Purgatives descend to the Intestines, and mix with the Juices of the Body: Whence we have a stronger Reason for rejecting the Use of these virulent Purgatives, than the Use of the virulent Emetics.

Regulation.

27. And thus we conceive the Matter of Purgatives may be reduced to a tolerable Degree of Simplicity; yet so as to leave Variety enough for suiting the different Diseases and Constitutions where Purging is required. The Nature of our Design will only permit us to indicate, as we go along, the Heads of this general Enquiry into the Means of reducing Pharmacy to an elegant and useful Simplicity; the Introduction whereof is not to be expected from private Hands.

EXPERI-

EXPERIMENT III.

A facile and simple Method of preparing a safe and effectual Sudorific.

28. If an Ounce of refined Camphire be beat, *A Sudori-* and ground, in a Marble Mortar, with two *fic prepa-* Ounces of blanch'd Almonds; the Camphire *red.* will be thus subtilly divided, and brought into an uniform Mass, fit for the forming of Pills, Boluses, &c. so as to be commodiously taken in the Way of a Sudorific, Discutient, or Perspirative Remedy; the Dose whereof may be assigned betwixt the Limits of three Grains and forty.

29. Sudorific, Perspirative, and Alexiphar-*Uses.* mic Medicines, make a large Part of the common Dispensatories: We judge that their Places may be advantageously supplied by a few powerful ones of approved Virtues; among which we esteem this of Camphire as a principal one, or at least superior to *Gascoign's Powder*, *Lapis Contrayervæ*, *Bezoar*, &c. whose Virtues at best appear to be small.

30. We are sensible that the Qualities of Camphire are not universally agreed on by Physicians; some esteeming it hot, and others cold; some of great, and others of little Efficacy. However, the Case is not to be decided by Authorities, but Experience; which seems to declare that Camphire is one of the most powerful, most immediate, and most innocent Perspiratives, Sudorifics, and Alexipharmics hitherto known: For a large Dose of it, suppose a Scruple or more, being dissolved in Spirit of Wine, and given to a healthy Person, does not increase the Pulse, or excite a præternatural Heat; but rather causes a remarkable

Coolness and Composure, with a gentle Sweating, or Increase of Perspiration. So little have the Virtues of this Medicine been understood; or so little can the Virtues of Medicines be deduced from their apparent Properties, or from reasoning *a priori*!

31. The natural and medicinal History of this Drug well deserves to be traced: It appears to be an essential Oil, of peculiar Properties; tho' some would have it a Rosin, and others a Gum. Certainly it stands alone, as a Thing *sui generis*; or a Body wherein the Nature of Rosins, Gums, and essential Oils, all meet in some Degree. It is perhaps one of the most discutient and subtile Remedies hitherto discovered: Whence it proves highly anodyne, perspirative, and preservatory. And we judge, from certain Observations and Experiments, that if the full Virtues of this Concreate, both internal and external, were sufficiently known, it might supply the Place of numerous other Drugs and Preparations, to the Ease and Advantage of Pharmacy.

*Farther
Uses.*

32. In particular, we would recommend this Medicine to be used instead of the common sudorific Decoctions of the Woods, in Cases both of the recent and inveterate *Lues Venerea*: It may also be advantageously mixed along with the Balsams, or fine Turpentine, commonly used at the close of that Distemper. In short, we recommend it in all inflammatory, putrid, pestilential, and even maniacal, Diseases. And whoever has the Secret of prudently joining this simple Medicine along with Nitre, may, as we apprehend, perform Cures scarce to be expected from other Medicines frequently used for the same Purposes.

EXPERI-

EXPERIMENT IV.

An easy and simple Method of procuring a safe and powerful Alterant.

33. If an Ounce of well purified Nitre, *An Alter-*
and two Scruples of Cochineal in Powder, *beant from*
boiled in five or six Ounces of Water; and the *Nitre.*
Solution be filtred, and afterwards evaporated
to Driness, keeping the Matter stirring as it
thickens; a fine red or purple Powder will be
left behind; that is, the Nitre will be thus dis-
guised, and reduced to a Form fit for taking in
the Way of Bolus, Powder, or Solution, with any
convenient Vehicle.

34. Nitre thus prepared, in order to conceal *Uses.*
so common a Thing, we judge to be an extremely
safe and useful Alterant, capable of produ-
cing considerable Effects in the Body, without
causing any disturbance, or sensible Evacuation,
unless in the Way of a Diuretic; in which
Respect it operates as an Evacuant.

35. It is remarkable of Nitre, that it may *Virtues.*
with Safety be injected into the Blood. *Mal-*
pighi injected six Ounces of its Solution into the
Jugular Vein of a Dog, without observing any
other Effect than its proving diuretic. It is far-
ther observable of it that it heightens the florid
Colour of extravasated Blood, and excellently
preserves it from Putrefaction; yet does not li-
quify fresh and warm Blood, as has been ima-
gined, but somewhat thickens it, almost in the
Manner of a Mucilage: Which may give us the
physical Reason of many of its Effects in the Body;
as particularly its allaying Inflammations and
Fevers, its stopping Hæmorrhages, curing the
Spitting of Blood, &c.

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36. If the medicinal Virtues of this simple Medicine were to be enumerated, as they stand confirmed by competent Experience, perhaps they would prove more numerous than those of almost any Medicine hitherto known. It has been found serviceable in the Stone, and Stoppages of Urine; in Deliriums, in malignant Fevers, in Diarrhoeas attending the confluent Small Pox, &c. so as to prove a Kind of general Remedy. And as all these Excellencies of the Medicine are joined with that desirable Property of being innocent, or scarce any Way prejudicial to the Body; it may seem strange that it should be so little used, or that Medicines no Way comparable to it should be preferred before it.

Whence
disesteemed 37. Possibly the mixing of Nitre with other Medicines may have occasioned its Virtues to be less known, or observed; perhaps that Humour of changing Medicines, almost every Day, may not have given it the Opportunity of shewing itself; but chiefly that strange Method of jumbling many Simples together in one Medicine, seems to have prevented the due noting of the Effects of this and other simple Remedies. We, therefore, wish that the *Medicinal History of Nitre* were drawn up, with Care and Judgment; as being persuaded, that both Pharmacy and Medicine might, by means thereof, be brought much nearer to Simplicity and Perfection than they are at present.

EXPERIMENT V.

An artificial Method of preparing a powerful and innocent Strengtheners.

38. We put half a Pound of the best *Peruvian Bark*, reduced to fine Powder, into a proper Glass, and poured upon it two Quarts of Spirit
of

of Wine; then shaking them well together, set ^{An-essen-} them to digest in a Sand-heat for two or three ^{tial Ex-} Days, till the Spirit of Wine appeared of a ^{tract of} deep red Colour, inclining to Purple. We ^{the Bark.} now strained the Tincture through a close Linen, and committed the Fæces at last to the Press. Then returning the Pressings, or remaining Powder, into the same Glass, we poured thereto two Quarts of strong White Wine, and again set the Matter to digest for two or three Days; then strained as before. After this we put the two Liquors into a Glass-Body, and distilled off a large Part of the Spirit of Wine; then evaporated the Remainder in a glazed Vessel, taking Care to keep the Matter stirring, and washing down, with some of the Spirit of Wine, the resinous Parts that adhered to the Sides of the Vessel. When the Matter began to grow thick, we added to it three Ounces of the Syrup of Orange-Peel; and thus brought the Whole to the Consistence of an Extract.

39. This Method of extracting the Virtues of ^{Its History} the Bark is the Invention of M. Charas; who experienced its Success in a large Practice for fifteen Years, wherein he never found it fail him, for the Cure of all Sorts of Intermittents. We have ourselves also had a competent Experience of its Success; and found it answer better than any other Preparation of the Bark we have seen: Whence we judge it the best Manner hitherto known of preparing an Extract from the Bark, so as to render it more innocent and effectual.

40. The Process was formed upon this Suppo- ^{Rationale:} sition, That the Bark contained a Resin and a Salt for its principal component Parts; to the Extraction whereof the two Menstruums are well adapted. And, in Effect, we find that Spirit of Wine does extract a Kind of Resin from the

Bark; and Wine such a Part as renders it able to cure some Kinds of Intermittents in certain Constitutions: Whence these two Menstruums, doubtless, take up the more medicinal Parts of this Substance, leaving its more woody or fibrous Part behind; which probably occasions that Stoppage and troublesome Weight at the Stomach we often hear complained of after taking large Quantities of the Bark in Substance.

41. The two finer and more medicinal Parts of the Bark being thus extracted, they are commodiously joined together again by the Interposition of the Sugar contained in the Syrup; so as to form an elegant Whole, that may be aromatized at Pleasure with the essential Oil of Mint, Cinnamon, or Cloves.

Regimen.

42. The Dose, and Method of exhibiting this Preparation of the Bark, are the same as the common; and though a much larger Dose should be given, it has not been found to produce any ill Effect. The Use of this Medicine is also attended with a quicker Recovery of the natural Complexion, Vigour, and Freshness, than the Use of the crude Bark. And as the Medicine appears to be thus rendered so powerful and innocent, perhaps it may be proper to try it also in some other weakening Distempers, besides Intermittent Fevers.

*Eleosaccharums
recommen-
ded.*

43. There are many other powerful and innocent Strengtheners, besides this Preparation of the Bark; among the principal whereof come the capital Aromatics, Cinnamon, Cloves, Nutmeg; or rather their essential Oils; which being made into *Eleosaccharums*, afford as potent Cordial Medicines, in a commodious Form, as can well be expected. But if more compounded Medicines are required, we would recommend the Use of a compound *Eleosaccharum*, consisting of

of a few select aromatic Oils, and the richest Gums and Balsams, as one general Cordial, or compound Strengtheners. And thus a Medicine might be easily contrived, that should collect in itself, or concentrate, the Cordial Virtues, dispersed in several capital Ingredients. Thus, for Example, Camphire, Balsam *Peru*, Balm of *Gilead*, the essential Oils of Cinnamon, *Lignum Aloes*, Myrrh, &c. are all homogeneous, and capable of being united either alone, or with Spirit of Wine, or Sugar; so as to be given with all desirable Advantage and Convenience.

EXPERIMENT VI.

A ready Method of procuring a safe Quieter, or Anodyne.

44. We took half an Ounce of Opium, and dissolved it with a gentle Heat in five or six times its own Quantity of fair Water; then straining the Solution, and exhaling away the superfluous Moisture, in a temperate Sand-heat, we reduced the Matter to a dry Substance; which being ground in a Glass-Mortar, with twice its own Weight of hard Loaf-Sugar, seems to afford us one of the best or mildest Preparations of Opium; and may be given from one Grain to three or four for a Dose.

45. By dissolving the Opium in Water, we get rid of its more gross and resinous Parts, which are found much more pernicious than the rest; and by dividing its Parts afterwards, with Sugar, we render the Medicine more uniform, resolvable, and miscible with the animal Fluids; and can thus the better adjust its Dose. But still this Medicine is not without some pernicious Property; nor is there any way known

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known to render the Use of Opium perfectly safe and innocent in all Constitutions : For if a large Dose of it be given, it is apt to disturb or cloud the Head, cause a Vertigo, Delirium, or Convulsions ; in particular, it proves prejudicial to the Stomach and Intestines, which it is apt to inflame and sphacelate ; thus acting, in some Degree, as a Poison : Whence a better Method of correcting it should be endeavoured after, or a more innocent Remedy be used in its Stead. A Mixture of Nitre and Camphire, we apprehend, may supply its Place on many Occasions, without any Fear of Danger or Inconvenience.

Regulation of Pharmacy.

46. Thus we have endeavoured to give an Instance of a simple and safe Preparation in each of the four general Tribes under which we conceive all Medicines may be commodiously ranged ; viz. Evacuants, Alterants, Strengtheners, and Quieters. If the Method we have here observed were pursued to its due Length, it might, doubtless, terminate in the certain Discovery of a few simple, elegant, innocent, and powerful Remedies ; at least it would enable us to throw out, as dangerous, noxious, or poisonous, a large Part of our present *Materia medica*, and pharmaceutical Preparations ; and a considerable Part thereof, as almost useless, or insignificant : Whence some tolerable Degree of Perfection in Pharmacy might be obtained.

47. Thus all the Medicines that have Lead in their Composition are scarce to be trusted for internal Use. We have various Instances of the poisonous Nature of this Metal ; as particularly among the Workmen at the White-Lead Houses, the Colourmen, or Grinders of Ceruse, and those who any way work in Lead. And it were sufficient to banish the frequent internal Use of

Saccha-

Saccharum Saturni, the *Tinctura antiphibetica*, &c. to read, in the *Miscellanea curiosa* *, how many Men were poisoned by drinking acid Wine rendered sweet with Litharge.

48. But Metals do not act in the Body till they are once dissolved: Whence crude Mercury, swallowed in large Quantities, proves harmless, through the Want of a Menstruum in the Stomach, &c. to dissolve it. But when crude Mercury is dissolved by its proper Menstruum, as in the Preparation of Mercury-Sublimate, we see it becomes one of the strongest Poisons. Lead, Iron, and Copper, being much more easily dissolved than Quicksilver, are seldom taken without some remarkable Effect; which must necessarily prove the greater, the more of an acid, or, in the Case of Copper, even alkaline Humour, is lodged in the Stomach or Intestines: Whence we derive a physical Reason why these Metals often produce different Effects in different Constitutions. The internal Use of the *Crystals of Silver*, though sometimes successfully given in dropfical Cases, should hardly be trusted, on account of their corrosive Acrimony; which has sometimes occasioned bloody Stools, and extreme Weakness. The common Tinctures of Copper, and Solutions of blue Vitriol, can scarce be taken internally with Safety; as being not only emetic, but in some Degree corrosive and poisonous. Even the *Aurum fulminans*, though highly esteemed by some as an internal Medicine, cannot be safely given, unless it has been first well washed from its Salts, and does not meet with a suitable acid Solvent in the Stomach: For in both these Cases it may have dire Effects; of which there have

* Decad. III. Obs. 30.

been remarkable Instances: Iron and Tin have not been found so pernicious to the Body, but rather beneficial; especially Iron, when prudently prepared and used. Indeed, of all the Metals, Iron seems to be the most innocent, and sufficiently powerful, tho' dissolved in so weak a Menstruum as Wine. And as this is the Result of our Method of Rejection applied to Metals and metalline Preparations, so we apprehend that if the same Method were applied to the whole *Materia medica*, there would thence result the discovery of safe and powerful Medicines for the Cure of all ordinary Diseases: Whence we would recommend this Kind of Procedure to those who regard the Improvement of Pharmacy and Physic.

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, That certain Simples are naturally better prepared for medicinal Use, than by the common chemical Treatment; such in particular are Ipecacuanha, Jalap, Rhubarb, Mechoacan, &c. Tables, or Catalogues, of which Kind of Simples ought to be formed, in order to abridge and perfect Pharmacy *a*).

2. That most of the Emetics in common Use, especially the antimonial Kind, are virulent and somewhat poisonous, compared to that milder one of Ipecacuanha *b*.)

3. That many of the common violent Purgatives are of an actually poisonous Nature, and therefore should be artificially corrected, or else make room for more innocent Kinds to be used in their Stead; particularly the purging *mineral Waters*, Manna, Rhubarb, &c.

a) Exp. I.

b) Exp. II.

4. That

4. That the more violent and poisonous Purgatives, such as Elaterium, Coloquintida, Scammony, Hellebore, &c. may have their poisonous Quality mitigated, or taken away, by boiling in Water and other Expedients *a*).

5. That the Effects of the poisonous Purgatives are considerably greater in the Body than the Effects of the poisonous Emetics *b*).

6. That the two principal Tribes of Evacuants, viz. Purgatives and Emetics, are reducible to a few simple and easy Preparations *c*).

7. That Camphire has considerable Virtues, as a Perspirative, Sudorific, and Resolver; being capable of uniting with oily Substances, and bearing a Relation to essential Oils, Rosins, Gums, and Balsams *d*).

8. That purified Nitre has many medicinal Virtues; so as advantageously to supply the Place of numerous other Medicines *e*).

9. That this purified Nitre has a great Power of preserving the Blood uncorrupted, fresh, and florid *f*).

10. That many of the medicinal Virtues of Nitre do not depend upon its liquifying, but rather upon its jellying the Blood *g*).

11. That the Perfection of Physic and Pharmacy may have a considerable Dependence upon the medicinal History of Nitre *h*).

12. That the *Peruvian* Bark may be rendered more innocent and effectual than when given in Substance, for the Cure of Intermittents, &c. by Means of a proper Treatment, or by extracting and uniting its saline and resinous Parts with a suitable intermediate Substance *i*).

13. That this Bark appears to contain three very different Parts in a loose Texture; viz. a rosin, a salt, and a woody Substance *k*).

a) Exp. II. *b*) ib. *c*) Exp. I. III. *d*) Exp. III.
e) Exp. IV. *f*) ib. *g*) ib. *h*) ib. *i*) Exp. V. *k*) ib.

14. That

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14. That possibly the resinous and saline Extracts of the Bark may be serviceable in curing more Diseases besides Intermitting Fevers; and that probably the frequent Failure of the common Infusions and Extracts of this Drug are owing to their containing much of its resinous Part without the saline one, or the saline Part without much of the resinous; and not a due Mixture and full Proportion of the two, as they are naturally found in the Bark itself: Whence the Substance has generally proved more effectual than any of those imperfect Extracts, Tinctures, or Infusions *a*).

15. That powerful Strengtheners, or Cordials, are obtainable from a Mixture of the richest Balsams, and essential vegetable Oils *b*).

16. That Opium may be so prepared as to become more innocent than in the common Methods of treating it *c*).

17. That a less noxious Quieter is wanted than Opium, and may, in some Measure, be supplied by Nitre and Camphire *d*).

18. That no Preparation of Lead can be long or freely used internally, without considerable Hazard *e*).

19. That the common Solutions and Preparations of Copper, Silver, Gold, and Mercury, are hardly proper for internal Use; nor even Tin and Iron, unless prudently prepared with gentle Menstruums, and cautiously given *f*).

20. That there are rational Grounds to expect some considerable Improvements in the present State of Pharmacy and Medicine, by a due Enquiry, and a proper Use of the Means conducive to this End *g*).

a) *Exp.* V. *b*) *ib.* *c*) *Exp.* VI. *d*) *ib.* *e*) *ib.*
f) *ib.* *g*) See the whole Lecture, *passim*.

LECTURE XVII.

CONTAINING

MINERALOGY; or the Art of Mining:
 With the previous Operations to Metallurgy; viz. Roasting, Stamping, Washing, and the Business of Fluxes.

1. **W**E are now entering upon a large, and *the Sub-*
 extremely useful Branch of Chemistry; *je&.*
 the Business of *Mineralogy* and *Metallurgy*.

2. By *Mineralogy* we understand that previous *Minera-*
 Part of *Metallurgy*, which teaches the Ways of *logy, what.*
 finding, judging, and digging Mines; with the
 Uses of Salts and Earths for making Fluxes, in
 order to the assaying and smelting of Ores for
 their Metals.

3. By *Metallurgy* we understand the Perform- *Metallur-*
 ance of those several Operations required to se- *gy, what.*
 parate Metals from their Ores, for the Uses of
 Life. And according to this Distinction we shall
 bestow one Lecture upon *Mineralogy*, and another
 upon *Metallurgy*, in the Sense we have here ex-
 plained them.

4. *Mineralogy* is an Art that requires a confi- *Requisites*
 derable Compais of Knowledge, before it can be *to Minera-*
 practised to Advantage: For as this Art includes *logy.*
 the Discovery, Sinking, and Working of Mines;
 it requires a competent Skill in the Nature, Efflu-
 via, and Effects of mineral Matters, whether
 Earths, Salts, Sulphurs, Stones, Ores, Bitu-
 mens,

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mens, Gems, or Metals. It likewise requires a Knowledge of the internal Structure of the Earth, and its various *Strata*; with a competent Skill in subterraneous Architecture, Mensuration, Hydraulics, Levelling, and Mechanics; without which we can never judge what Mountain, Plain, or Valley, is proper to be dug; in what Manner to dig it; how to discharge the Water that may flow in upon the Works; how the Beds of Ore and Stone will dip, or run; how the various Kinds of Earths, Marble, and other mineral or metallic Matters, are to be cut through, or broken; or how the general Process of Mining should be conducted, in order to procure, with the least Expence, or bring to open Day, the principal Matter or Ore required.

Qualifications of a Metallist. 5. And even when all these Difficulties are conquered, no more than half the Work is effected; and still the End can never be obtained without a tolerably exact Knowledge of several chemical Operations; viz. Trituration, Torrefaction, Lotion, Calcination, Cementation, Fusion, Amalgamation, Vitrification, Sublimation, Distillation, and the like: Whence it might be laid down as a Rule, That every directing Metallist should not only be tolerably versed in the several Parts of Natural Philosophy, but particularly be well acquainted with *Chemistry*.

6. And perhaps it may not be improper to intimate, that many metallurgical Attempts have miscarried, merely for Want of a competent Skill to conduct them. The under Workmen in this Way are generally a head-strong, ignorant People, that cannot be managed without the Use of some good political Rules, and a Knowledge much superior to their own. Yet how little soever the Art of Mineralogy may have been under-

understood, History affords us numerous Exam-
 ples of plentiful Fortunes and immense Treasures
 raised from Mines, as well by private Persons,
 as by particular States and Kingdoms. But the
 Vulgar, and even Philosophers unversed in
 Trade, generally reckon the Business of Mining
 unprosperous, and at best precarious and un-
 certain; especially when compared with Agri-
 culture, or other Arts exercised more in the
 open Day.

*The Success
 of Mining.*

7. The Truth is, Mines are liable to many
 Contingencies; being sometimes poor, some-
 times soon exhaustible, sometimes subject to
 be drowned, especially when deep, and some-
 times hard to trace. Yet there are many In-
 stances of Mines proving highly advantageous
 for hundreds of Years. The Mines of *Potosi*
 are, to this Day, worked with nearly the same
 Success as at first; the Gold Mines of *Crem-
 nitz* have been worked almost these thousand
 Years; and our *Cornish* Tin-Mines are extreme-
 ly ancient. In general, the Profit of Mines,
 compared with that of Agriculture, is immen-
 sely greater in the same Time, so as to compen-
 sate largely for its Uncertainty. Even Lead-
 Mines generally yield twice or thrice the Re-
 turns of the richest Soils, cultivated in the ordi-
 nary Manner, either by Nature or Art. What
 then shall we say of the Mines that are rich in
 the nobler Metals? The neat Profit of the Sil-
 ver alone, dug in the *Misnian* Silver-Mines of
Saxony, in the Space of eighty Years, is computed
 at an amazing Sum*.

*The Profit
 of Mines.*

8. Many Mines have been discovered by Ac-
 cident. A Torrent first laid open a rich Vein
 of the Silver-Mine at *Friberg* in *Germany*. Some-

*Accidental
 Discoveries of
 Mines.*

* See *Petr. Albin. in Chronic. Misn. Miner. German.*

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times a violent Wind, by blowing up Trees, or overturning Rocks, has discovered a Mine. The same has happened by violent Showers, Earthquakes, Thunder, the firing of Woods, or even the Stroke of a Plough-Share, or a Horse's Hoof.

The Art of Mining. 9. The Art of Mining does not wait for these favourable Accidents; but directly goes upon the Search and Discovery of such mineral Veins, Ores, or Sands, as may be worth the working for Metal.

How to be practised. 10. The artificial Investigation and Discovery of Mines depends upon a particular Sagacity, or an acquired Habit of judging, from particular Signs, that metallic Matters are contained in certain Parts of the Earth, not far below its Surface.

Signs of a Mine. 11. The principal Signs of a latent metallic Vein seem reducible to general Heads; such as (1) the appearance of certain mineral Waters; (2) the Discolouration of the Trees or Grass; (3) Pieces of Ore on the Surface of the Ground; (4) the Rise of warm Exhalations; (5) metallic Sands, and the like: All which are so many Encouragements for making a stricter Search near the Places where any Thing of this Kind appears. Whence Rules of Practice might be formed for reducing this Art to a greater Certainty.

The Art of Boring. 12. But when no evident Signs of a Mine appear, the skilful Mineralist usually bores the Earth in such Places as, from some Analogy of Knowledge, gained by Experience (or by observing the Situation, Course, or Nature of other Mines) he judges may contain Metal.

13. This Method of Boring consists in the Use of a Set of Scooping-Irons, made with Joints, so as to be lengthened at Pleasure, and thrust down to a considerable Depth below the Surface of the Earth,

Earth; so as when drawn out again to bring back Samples of the Earth, or mineral Matter, from the Depth to which the Iron descended; much after the Manner that Samples of Sugar are taken out of the Hoghead by the Instrument called a *Reft*.

14. After a Mine is found, the next Thing to be considered is, whether it may be dug to Advantage. In order to determine this, we are duly to weigh the Nature of the Place, and its Situation, as to Wood, Water, Carriage, Healthiness, and the like; and compare the Result with the Richness of the Ore, the Charge of Digging, Stamping, Washing, and Smelting. This is a Matter of common, civil, or œconomical Prudence.

When Mines may be dug to advantage.

15. Particularly the Form and Situation of the Spot should be well considered. A Mine must happen either (1) in a Mountain, (2) in a Hill, (3) in a Valley, or (4) in a Flat. But Mountains and Hills are dug with much the greatest Ease and Convenience; chiefly because the *Drains* and *Burrows*, as the Miners call them, that is, the *Adits*, or *Avenues*, may be therein readily cut, so as both to drain off the Water, and to form Gangways for bringing out the Load, or Ore, &c.

16. In all these four Cases *, we are to look out for the Veins, which the Rains or other Accidents may have laid bare; and if such a Vein be found, it may often be proper to open the Mine in that Place, especially if the Vein proves tolerably large and rich: Otherwise the most commodious Place, for Situation, is to be chosen for the Purpose; viz. neither on a Flat, nor on the Top of a Mountain, but on its Sides: For the Mineralist is always to exercise his Judgment

Mines, where to be opened.

* See §. 15.

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in the due Choice of a Place to begin the Work.

The best Situation of a Mine. 17. The best Situation for a Mine is a mountainous, woody, wholesome Spot, of a safe, easy Ascent, and bordering upon a navigable River. Such a Place therefore being the Standard of Goodness, all others may be judged of as they approach to, or recede from it.

Requires Wood. 18. Wood is indispensably necessary for making the necessary Instruments, Engines, and Huts; as also for fencing the Pits, or Avenues, and supporting the Rock, where large Caverns are made by digging away the Ore: And again, for supplying Fuel to the melting Works; unless where Pit-Coal will serve the turn. But though no Wood or Coal should grow upon the Spot, it may often be supplied by Means of a navigable River, or cheap Carriage. And thus there are some rich Mines, in the hotter Climates, without so much as a Shrub growing near them.

Water. 19. Plenty of Water should never be wanting, and is best supplied by a River, from which it may be commodiously derived, by Pipes, into the Lavaderos, Smelting-Huts, &c. or even brought into the Burrows themselves, and made to work the subterraneous Machines. These are Conveniencies not to be expected from casual Rains, or the Torrents of the Mountains.

Good Roads. 20. The Roads and Conveniencies of Carriage, to and from the adjacent Parts, must be likewise regarded; as well for the Sale of the Metal produced, as the Conveyance of Goods and the Necessaries of Life to the Workmen: For it rarely happens that Provisions are afforded by the Spot where Metals are found.

21. The Places abounding with Mines are generally healthy; as standing high, and every way

Way exposed to the Air : Yet some Places where *And wbol.*
 Mines are found prove poisonous, and can by *some Air.*
 no means be dug, though ever so rich. The
 Way of examining a suspected Place of this
 Kind is, to make Experiments upon Brutes, by
 exposing them to the Effluvia or Exhalations,
 in order to find the Effects thereof.

22. But a considerable Advantage may some-*Metals ob-*
 times be made, without the Labour and Expence *tainable*
 of Digging : For as Springs and Rivulets are *without*
 frequently the Outlets of Mines, it may happen *Mining.*
 that the Sand of such Waters shall be worth the
 washing for Metal ; in which Manner large
 Quantities of Gold-Dust are often procured.
 And hence it appears to be, that the Sands of
 many rapid Rivers, and even the Sands of the
 Sea in some Places, contain Gold ; though the
 latter in so small a Proportion as seldom to be
 worth the Washing. But the Sand of such Ri-
 vers wherein stamped Ores are continually wash-
 ed may frequently deserve to be assayed.

23. The Veins of a Mine differ greatly from *The differ-*
 each other, in Depth, Length, and Breadth. *ent Veins.*
 Some stretch obliquely from the Surface towards
 the central Parts of the Earth ; and these are
 called *deep Veins* : Others lie shallow and circu-
 lar, so as to encompass a large Space ; these are
 termed *spreading Veins* : Others possess a great
 deal of Space, both in Length and Breadth ;
 and these are called *accumulated Veins* ; being no
 more than a Space possessed by a Group of Fossils
 of one certain Kind. But to give the History
 of Veins, and Fibres, which are smaller Veins,
 their Differences, their Directions, their Inter-
 sections, their different Goodness, their Discon-
 tinuations, their Rising, Falling, &c. would be
 a large Work. Let it, however, be observed,
 that these Things seem to proceed in a certain
 B b 3 order,

order, though the Laws thereof have not been so well observed as to afford us sure Rules of Practice : Whence it sometimes happens, that after a Vein has been successfully traced for some time, it dips, breaks off, or takes a different Course, leaving the Workmen as it were at Fault.

How to be traced.

24. When a Vein of Ore is found, and all Things prepared for the Work, if the Vein be of the deep Kind * it is first to be laid bare, and a Pit to be sunk upon it ; at the Mouth whereof a Shed is to be raised, and a Crane, or Barrel and Winch, fixed, for drawing up the Ore. The Pit is to be sunk either perpendicular or oblique, according as the Vein happens to run.

And dug.

25. It is also usual, in this Case, to cut a Burrow, or Adit into the Side of the Hill. This Burrow is usually cut twice as high as wide, that the Workmen may commodiously pass along it with their Barrows and Burdens ; being for that Purpose usually about seven Foot and a half high, and almost four Foot wide. If this Side Pit reaches to the sunk Pit, it becomes a true Burrow, open at both Ends ; and thus renders the Work more facile and commodious, as the Ore may be now wheeled out in Barrows, instead of being craned up to the upper mouth of the Pit. After the same Manner it is usual to dig many Caverns into the Sides of the Mountain, in order to scoop out the Ore : So that sometimes there are thus several Burrows made, to the Ease and Advantage of the Work.

The Burrows, how made.

The Digging various. By the Spade.

26. The Art of Digging the Veins varies according to the Nature of the Vein, or according as it is soft or hard. The soft Vein is generally dug with the Spade, and turned out into

* See above, §. 23.

wooden Trays, placed underneath to receive it :
 But the hard Veins are knocked out with a *By the*
 Gad, or Kind of Chizzel, and Hammer. But *Gad.*
 if the Ore is so hard as to be incapable of break-
 ing in this Manner, they usually soften it with *By Fire.*
 Fire; which has the Power of rendering the
 hardest and most flinty Stones brittle and friable.
 But a still more expeditious Method is the work- *By Bla-*
 ing with Gunpowder; by Means whereof much *sting.*
 of the hardest Rock may be shivered and split
 in a very little Time; a small Parcel of Powder
 being laid in a long Hollow cut for the Purpose,
 after the Nature of a Gun-Barrel, and fired as it
 were at a Touch-hole; a small Vent, where the
 Quick-match is applied, being left for the Pur-
 pose, and the rest of the Orifice being hard
 stopped up with Clay.

27. The Manner of pursuing and digging all *The Design*
 Sorts of Veins, the Ways of under-propping, and *of the fol-*
 discharging the Water from the Works, the *lowing Ex-*
 sinking of Air-shafts, curing of Damps, and *periments.*
 the like, we have no time to describe *; our
 more immediate Business being the Treatment of
 the Ore, after it is dug and brought to open
 Day. For this Purpose there are certain pre-
 vious Operations required, of which we propose
 to exhibit Examples. Our *first* Experiment,
 therefore, will shew the Method of Roasting
 sulphureous or arsenical Ores; the *second* will
 shew the Method of Stamping and Washing of
 Ores; and the *third*, the Method of preparing
 Fluxes.

* See *Agricola de re metallica.*

EXPERIMENT I.

*The Method of Roasting Ores.**Mundic
roasted.*

28. We took a Pound of the common *Cornish* Mundic, and breaking it into small Lumps, exposed it upon the Grate of a Furnace, whilst the Fire was made below; and thus at first we gently heated and torried the Mundic, but afterwards by Degrees increased the Fire, so as to make the Lumps glow, or appear red hot; in which State we kept them for half an Hour, or till no more sulphureous Vapour or Stench rose from them.

*The Experiment
explained.*

29. This Experiment shews the common Method of Roasting Ores, in order to discharge their sulphureous, arsenical, or antimonial Parts, that might otherwise hinder their Fusion, or else carry off a considerable Proportion of the truly metallic Matter in melting. For fear this metallic Matter should fly off, we made the Fire gentle at first; but increased it, by Degrees, till the Lumps became red hot, because otherwise the Sulphur would not quit its hold; for Sulphur requires a naked Fire and the Assistance of the open Air, before it will burn, or go entirely off*.

*And applied,
to the
kindly
Ores.*

30. The richer and more tractable Ores have no Occasion to undergo this previous Operation of Roasting, but are usually committed to Fusion soon after being dug up, and separated from their Stone, or Mine. However, if they contain any considerable Quantity of Sulphur, or Arsenic, it is usual to roast even these a little.

* See *Let. II. passim.*

31. But some Copper Ores are so stubborn and refractory, or hold their Sulphur so tenaciously, as to require many Roastings before they will let it go: being either stamped or melted after every Operation, so that all the Parts may, at several Times, be equally exposed to the Fire, and have their Sulphur discharged.

*To be more
stubborn
Ores.*

32. In the large Way of Business this Operation is usually performed in a Trench cut somewhat aslope in the Ground, that the Air may have the freer Access at the Bottom: they first place a Layer of Billet-Wood in this Trench, and upon that a Layer of the Ore, in little Lumps, and so continue, interposing a Layer of Wood and a Layer of Ore, for three or four Stories; when the Pile being compleated, they set Fire thereto, and make it continue to burn slowly for several Days together, during which Time there rises a large Quantity of sulphureous Vapour, that may be perceived to a considerable Distance.

*In the large
Way.*

33. But when the Ore, by repeated Roasting, Stamping, and Fusing, is become tolerably pure, they now finish the Operation by throwing it into a particular Furnace, having a Funnel to increase the Draught; so as to make the Fire the stronger, and discharge the sulphureous Fumes in greater Plenty. And this Furnace is so contrived, that the open Flame of the Wood may play directly upon the Ore; whence all its volatile Part is separated, and the Remainder left fit for the last Stamping and Washing.

34. When the Ores contain a large Quantity of Sulphur, this usually sweats out and runs down into Cavities made on Purpose to receive it; whence it may be ladled out, and cast into Moulds. But perhaps the most frugal Method of roasting Ores, so as to save, or collect, all the

*The Sul-
phur, how
collected.*

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the Sulphur, or Arsenic, they contain, is not generally known and practised: For in the common Way, a large Proportion is lost, which might be collected by Means of a proper Hood, in the Form of Flowers; and also the rising Fume might, by a particular Structure of the Furnace, be made to pass into a large Vessel of cold Water, and there be condensed; as we see in certain chemical Distillations and Sublimations.

Vitriol obtainable in the washing.

35. After the poorer and more stubborn Sorts of Copper-Ore have been thus successively roasted, and come to be quenched in Water, or washed, they often impregnate the Water with a vitriolic Matter; so that sometimes profit may be made by evaporating these Waters, and suffering the Vitriol to shoot: For the acid Part of the Sulphur, here separated by the Fire, is greatly disposed to enter the metallic Part of the Ore, and dissolve it; so as to form an actual blue Vitriol, or Vitriol of Copper, which sells for a considerable Price.

Roasting generally profitable.

36. And here it should be remembered, that Ores rarely yield the less Metal for Roasting; unless the Fire were made too strong, especially at the first: For when the Yield proves small, the general complaint of the Smelters is, That the Ore, when sent to their Furnace, was too little roasted; though indeed the fault is often their own, in neglecting to make their Fire sufficiently brisk and strong from the first; which is a very considerable Secret for increasing the Yield of an Ore.

Tho' not always in imperfect Ores.

37. There are, however, some Reasons to believe, that many imperfect Ores lose considerably of their Metal by Roasting, especially when they are mixed with arsenical, or antimonial, Matters, which have a known Property of volatilizing the impurer Metals, and carrying them off

off in Fume : Whence, doubtless, it is that some poor Ores and Mundics are commonly treated with little Success.

38. The Remedy in this Case we apprehend *This Incon-* to be the due Use and Application of some *fixing* *venience* *remedied.* Substances, whether of an absorbent, alkaline, or neutral Nature; such as Quicklime, Kelp, or Pot-Ash, dry River-Mud, Clay, Iron-Filings, or the like, mixed or stratified along with the Ore. And by certain Additions of this Kind, we doubt not but the Yield of some poorer Ores might be considerably increased.

39. The Business of Roasting Ores may *Roasting* be improved, and reduced to a few easy Rules. *reduced to* (1) We see it is of two Kinds, or simple and *Rule, with* compound; that is, either with or without Ad- *regard to* dition. No Addition is wanted when the Ore *Additions.* proves rich, or in itself nearly of a metallic Nature, as some Ores are found to be. But Additions are principally required, when arsenical, antimonial, or sulphureous Matters are naturally mixed with the Ores *.

40. (2) The Fire is to be so regulated, from *The Fire.* the first, that only the lighter, or more volatile, sulphureous, or arsenical Fumes may go off; otherwise the more metallic Part also would fly away, and, without some proper Contrivance to catch it, be lost. Yet the Ore must feel the force of an open Flame at last; otherwise all the Sulphur, Arsenic, Antimony, and other immature mineral Substances, will not be dislodged.

41. (3) The more these immature Substances abound in the Ore, the gentler the Fire should be at first; and when the greater Part of them is thus exhaled, the Fire is to be quickened by a freer Admission of the external Air.

* See §. 38.

And Washing. 42. (4) Lastly ; Where such fixing Additions are used as are not metalline, for Example, Lime, Mud, &c. the unmetallick Parts ought again to be separated by Stamping and Washing, before Fusion, which would otherwise be hindered, or uselessly encumbered.

EXPERIMENT II.

The Method of Stamping and Washing of Ores.

Mundic stamped and washed.

43. We took the Mundic roasted in our former Experiment, beat it fine in a metalline Mortar, and searced it ; then putting it into a Buddling-Dish, we washed it in several Waters, taking care to separate the heavier Portion from the lighter, and drying this heavier Part, which is always the more metallic.

Washing and Stamping not always necessary.

44. These Operations of Stamping and Washing are not necessary in the richer Sorts of Ores, but are often absolutely required in the poorer and more flinty Kinds. If a large Quantity of mere stony Matter adheres to the Ore, it is sometimes knocked off with Hammers ; so as to leave the more metallic Part free from this barren or superfluous Substance.

Hard Ores, how softened.

45. If the Ore still proves hard and flinty, it is sometimes softened by lying, for several months, exposed to the open Air, which thus renders it fit for the Stampers ; though it sometimes also requires to be heated, or ignited, and quenched in Water, to fit it for that Purpose. Thus a large Heap of hard, and otherwise untractable, Ore may be heated red hot, by interspersing it with Billets, and setting them on fire ; after which it may readily be quenched, and rendered friable, by throwing cold Water upon it, or by passing a small Stream of Water through it, derived from some adjacent River. And sometimes this Operation must

must be repeated, before the Ore will grow soft and tractable.

46. It is usual to stamp most Ores in a State of Moisture or Wetness, to prevent the Avolation of their Dust or Powder; but especially such as require much washing to separate their barren and lighter earthy Parts, which would otherwise uselessly encumber the melting Furnace. To perform this Stamping the more commodiously, a Stream of Water is made to pass under the Stampers; so as to make various windings and turnings, and, in Part, run into certain Cavities, made on Purpose to catch and detain the heavier Matter, whilst the lighter is washed away to a greater Distance by the Current.

Ores how best stamped in the large Way.

47. But the Method of washing the Ores of the nobler Metals is more exact and curious; as in washing of Sand for Gold, on the Banks of the *Rhine* and *Danube*, where Gold is frequently found, especially in such Places where the Sand is raised into large Heaps, or a Kind of Mountains, by the Rapidity of the Stream.

The Ores of the nobler Metals how washed.

48. These Sands are usually washed by the Hand, in a long Trough, made for the Purpose, with a Descent or Current, and lined at the Bottom with Flannel; for thus the Sand being artificially agitated with the Hand, the lighter and larger stony Matter rises uppermost, whilst the heavier descends, and is caught in the Pores of the woolly Cloth at the Bottom; in the mean Time the lighter Matters are washed farther off by a Stream running down the Declivity. When the Flannel has thus collected a considerable Quantity of the richer metallic Matter, the whole Cloth may be easily taken off, and rinsed in a proper Vessel of Water, where all

Fine Gold Sand how washed.

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all the metallic Matter, before adhering to it, readily falls off, and sinks to the Bottom of the Vessel; and then, the Water being decanted, the Metal may be collected alone and dried. And this is the Method of procuring the Gold where the Sand is fine, or extremely small.

*The coarser
bow treat-
ed.*

49. In the larger Works, or where the Gold is mixed with big Sand, Gravel, or Stones, they make Use of Wire-Sieves, whose Meash is always of one certain Size; so as readily to transmit the fine Sand, or Gold Dust, and retain the larger Gravel and Stones behind: For it is extremely rare to meet with a Grain of Gold, in the Sands of Rivers, so large as a Barley-Corn. Whence this Method by the Sieve is highly serviceable, and conducive to the former Operation: For though a large Quantity of fine Sand thus passes the Sieve, it may be readily separated in the Trough, after the Method already described *.

*The End of
Stamping
and Wash-
ing.*

50. And this may suffice to shew the general and particular Methods of Stamping and Washing Ores. We see the End of these two previous Operations is to get rid of the Matters which are not metalline; that so the Furnace may not be uselessly employed upon such Substances as will themselves yield no Metal in the Fire, and only hinder the metallic Parts of the Ore from coming together, and affording a Yield answerable to the Expence and Trouble of the Fusion.

* § 48.

EXPERIMENT III.

Ways of preparing the strongest Fluxes.

51. We took four Ounces of red Lead, an Ounce of White Sand in Powder, and two Ounces of dry decrepitated Salt, and mixed them all well together in a Mortar; this Mixture we put in a clean *Hessian* Crucible, fitted with a Cover, and fused it in a Wind-Furnace for a Quarter of an Hour; then taking it out, and letting it cool, we broke the Crucible, and found the Salt at top, and a pure Glass of Lead at the Bottom: This Glass we carefully separated and kept apart, as a powerful Flux.

52. The Salt is of no other Use in this Operation, than to serve as a Flux to the Sand, and make it more readily unite with the Red Lead; so as to form a Glass without any great Violence of Fire, or the Necessity of detaining it long therein. So that by this Means a Glass of Lead may be readily prepared for the Purpose of artificial Gems*, or other Uses.

53. This Glass of Lead is an extremely useful Flux in the Business of assaying; and when kept long in Fusion, passes through the Pores of any common Crucible, almost like Water through a Sieve; so as, upon the Test, readily to vitrify, and carry off, all Sorts of metalline and mineral Matters, except Gold and Silver: On which Property, therefore, the Art of Cupelling depends.

54. Fluxes seem reducible to two general Kinds; viz. the *vitreous* and the *saline*. By the

* See *Leß. XIV. Exp. II. and V.*

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viz. the vitreous.

vitreous we understand all those which either have of themselves, or readily assume, a glassy Form in the Fire ; among the Principal whereof we reckon the Glass of Lead, the Glass of Antimony, and Borax.

and saline.

55. By the *saline* Kind of Fluxes we understand all those that are composed of Salts, whether Tartar, Nitre, fixed Alkali, or the like. And among the Principal of this Kind we reckon the Black Flux, which we formerly shewed how to prepare *; also Sandiver, Kelp, &c.

Their different Uses.

56. The vitreous Kind seem more immediately destined to act upon the stony or vitrescible Matter, wherewith stubborn Ores are frequently mixed ; and the saline Kind, to act more immediately upon the Ore itself, for the due Exclusion or Separation of the Metal.

Some Ores require no Flux.

57. The more kindly Ores require no Flux to make them run thin, or to afford all the Metal they contain. And sometimes Ores are so kindly as to contain their own Fluxes within themselves. Thus we have met with Copper-Ores, which being barely ground to Powder, and melted, without any Addition, in a common Wind Furnace, have yielded as much, or even more pure Metal at the first Operation, than we could obtain from them by Means of the usual Fluxes. Whence we see that artificial Fluxes are not always necessary ; or that the principal Use of them is for the stubborn or less

Metallurgy improvable by discovering cheap Fluxes.

tractable Ores. And these are sometimes so exceedingly hard to fuse, and bring to a metalline Form, that it requires the utmost Power of Art to treat them advantageously in the larger Way of Business, where no considerable Expence can usually be allowed for Fluxes.

* See *Lect. I. Exp. II.*

58. On this account it is that many Mines remain unwrought, as being intractable without great Charges. Whence the Improvement of the Business of Fluxes, so as to render them cheap and effectual, might greatly contribute to the Improvement of Metallurgy. We would therefore recommend to farther Enquiry what Matter it is, in the more soft and tractable Ores, which renders them so fusible, and easy to part from their Metal. Certain Experiments which we have made with this View seem to shew, that in Copper-Ores it is a Kind of bituminous Substance, capable of melting, by a strong Heat, into a soft and black kind of Glass.

59. Some of the most powerful and cheap simple Fluxes hitherto known are dried Wine-Lees, dried Cow-dung and Horse-dung, dried River-Mud, Fuller's Earth, Iron Filings, common Salt, Glass, Kelp, Pot-Ash, Sandiver, &c. which may be used in the larger Work; as Nitre, Tartar, Borax, Sal-Ammoniac, Mercury-Sublimate, &c. may in the smaller, or for the making of Assays.

60. As for compound Fluxes, they are numerous; almost every Operator having his favourite one. And certainly some Fluxes are better adapted than others to certain Ores. But perhaps a few general ones might be fixed upon, which should serve instead of all those hitherto commonly known and used. We will here recommend three, which are powerful, almost general, and not expensive.

61. (1) Take of Nitre, prepared by long boiling it in Lime-Water, of Sea-Salt melted in the Fire, Sandiver, and dry Wine-Lees, each one part; Glass of Lead, three Parts; and powdered Glass, eight parts: mix them all well together.

C c

This

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This Flux added, in an equal Weight, will fuse a very stubborn Ore.

62. (2) For a still stronger, take equal Parts of white Tartar, common Salt, and Nitre, prepared as above; calcine them to a white Powder, and mix therewith its own Weight of Glass of Lead; and of this Flux add two Parts to one of the stubbornest Ore.

63 (3) For a powerful saline Flux take of the strongest Soapboiler's Lees four Pounds, white Tartar and common Salt, melted in the Fire, each one Pound; boil them together with five Gallons of human Urine, to a dry Salt. This Flux is particularly proper where Sulphur and Cobalt abound, and render the Ore very-refractory.

The Improvement of Fluxes.

64. But the great Secret in the making and adapting of Fluxes, is not only to separate the Metal already ripened in the Ore, but even to mature and ripen the crude or immature Part of the Ore in the Fire. Something of this Kind, we apprehend, may be effected; as having reason to believe, that certain Fluxes, will obtain a larger Yield of Metal from certain Ores, than other Fluxes in common Use, though esteemed of the best, and though they are perhaps of the dearest Kind. Thus clean Iron Filings will often do more than Borax. But as the Scales and Crocus, or Rust, of Iron have been commonly used, instead of pure and perfect Iron itself, for a Flux, few Operators appear acquainted with the Excellence of perfect Iron employed for this Purpose. Many Advantages also are now commonly reaped by a prudent Mixing of one Ore with another of the same Denomination, and with the Slags or Recrements of Metals, in the Way of a Flux.

AXIOMS

AXIOMS and CANONS.

1. We learn from the preceding Enquiry, that to practise Mineralogy and Metallurgy to advantage, a considerable Knowledge in Natural Philosophy and the Operations of Chemistry is required *a*).

2. That many Miscarriages in mineral Attempts have been owing to the Want of a competent Skill in Mechanics, Hydraulics, and Chemistry *a*).

3. That the Profit attending the scientific Working of Mines is generally greater, and upon the whole more considerable, than that of Agriculture, or Merchandize *b*).

4. That there are two Ways of discovering Mines; *viz.* by Accident, and by Art: The latter whereof belongs to the intelligent Mineralist *c*).

5. That the Art of discovering Mines depends upon a certain Sagacity, which may be acquired by Use and Practice; or upon the Observation of particular Signs that generally denote a Mine; and again upon the Method of Boring, according to some Analogy of Knowledge, gained by being conversant with the common Appearances, Situations, and other Phænomena of Mines *c*).

6. That the Art of discovering Mines is reducible to Rule, so as not to be mere Conjecture, or Guess-work *c*).

7. That in general, Mines are to be first opened where a Vein is laid bare by accident or otherwise, especially if it prove large or rich: But where no such Encouragement appears, the

a) § 4—6. and Exp. I. II. III.

b) § 4—6.

c) § 8—13.

sides of Hills are preferably to be chosen for an opening *a*).

8. That a deliberate Consideration, and a competency of oeconomical Prudence, are usually required to determine before-hand, whether a Mine, after it is discovered, may be wrought to Profit *b*).

9. That the most perfect Situation of a Mine is to be mountainous, woody, easy of Ascent, healthy, bordering upon a navigable River, and good Roads *b*).

10. That Metals may be sometimes obtained to Advantage without Digging; or barely by washing the Sands of certain Springs and Rivers *c*).

11. That mineral Veins differ greatly from each other, and accordingly require different Methods of Digging, which may be reduced to standard Rules of Practice *d*).

12. That the Business of Mining is improvable by discovering better Methods of preventing or curing Damps in Mines, rendering poisonous Mines wholesome, or defending the Bodies of the Workmen against their ill Effects; as also by discovering better Methods of raising or discharging the Waters, following the Veins, breaking the Rock, bringing up the Ore, &c. *d*).

13. That the End of Roasting Ores is to discharge their sulphureous, arsenical, antimonial, or other rapacious Matters; which would otherwise carry off the purer Metal in the melting Furnace, and defraud the Account *e*).

14. That the richer Ores require neither Roasting, Stamping, nor Washing; but may be di-

a) § 14—16.

b) § 14—21.

c) § 22, 47—49.

d) § 23—26.

e) Exp. I.

rectly committed to the Smelting-Furnace, without Flux or Addition *a*).

15. That in order to roast Ores in Perfection *per se*, the Fire should be gentle at first, and afterwards increased to a Degree of Ignition in the Ore *b*).

16. That some Ores, joined with rapacious mineral Matters, may be advantageously mixed, or stratified, in Roasting, with proper fixing Ingredients *b*).

17. That Ores are seldom rendered the poorer, but generally the richer, for Roasting; unless the Fire at first be made too strong *b*).

18. That the Business of Roasting Ores is improveable, and reducible to a few easy Rules, with a View to render the Ore more pulverable, and discharge its volatile, sulphureous, and arsenical Parts; which, if retained, would, in strong Fusion, partly prevent the Separation of the purer Metal, and partly carry it off into the Air *b*).

19. That Metals, in their Ores are not those fixed Bodies they appear to be in the Bars or Ingots, into which they are brought by metallurgical Operations *a*).

20. That the Operations of Stamping and Washing are required only in the hard, flinty, and poorer Ores; the Design of these Operations being merely to separate the useless terrestrial, or flinty and stony Parts, which would otherwise encumber the Furnace and lessen the Yield.

21. That some hard Ores, may be softened, or rendered fitter for Stamping and Washing, barely by lying exposed to the open Air, which seems to turn some Parts of the Ore into a saline

a) Exp. I. II. III.

b) Exp. I.

matter, or Vitriol; whence a Kind of Friability or Softness is communicated to the Rest *a*).

22. That the hardest or stubbornest Ores may be softened, and rendered fitter for the Stampers, by being first ignited, and then quenched in Water; especially if this Operation be several Times repeated *b*).

23. That the two Operations of Stamping and Washing are, in good Measure, reducible to one, in the ordinary Ores; the Course of the Water being so directed under the Stampers, as immediately to carry off the lighter stony Matters, and leave the heavier or more metallic Parts behind *b*).

24. That the Sands of certain Rivers may, by a slight manual Operation, be sometimes washed for their Gold to considerable Profit *c*).

25. That the washing of Sand for Gold may be considerably expedited, by a proper Use of the Sieve *b*).

26. That Glass of Lead is a powerful Flux; so as to be capable of vitrifying, and carrying away with itself upon the Test, all the metallic or mineral Matters that are not either Gold or Silver *d*).

27. That the vitrescible Class of Fluxes are more adapted to operate upon the stony Parts of Ores, and the saline Class upon the Ores themselves, so as to separate their Metal *d*).

28. That the Business of Assaying and Refining Gold and Silver, depends upon that Property which Lead and the Glass thereof have of vitrifying, and carrying off upon the Test, all the known Matters, except the two nobler Metals *d*).

a) Exp. II. See also *Lea*. III.

b) Exp. II.

c) § 22, and Exp. II.

d) Exp. III.

29. That some Ores naturally contain their own Fluxes, and are therefore best assayed and smelted *per se a*).

30. That the Business of Metallurgy might be considerably improved, by discovering a cheap and general Set of powerful Fluxes *a*).

31. That an Enquiry into the Nature of the fusible Matter, naturally contained in the more kindly Ores, might lead to a Discovery of some cheap and powerful Fluxes *a*).

32. That the large Number of compound Fluxes might be reduced to a few general Kinds, capable of performing as much as all of them severally *a*).

33. That the greatest Improvement of Fluxes depends upon making and using them so as to mature the Ore, or otherwise cause a larger Yield than can be procured by the common Fluxes *a*).

34. That such maturing Fluxes may be, in some Degree, obtained by a farther Knowledge of the Properties, Affinities, or Relations betwixt Metals and Metals, Metals and Minerals, Ores and Ores, or Minerals and Minerals *a*).

a) *Exp. III.*

LECTURE XVIII.

CONTAINING

METALLURGY; or the Art of Assaying,
and working Metals from their Ores.

*The Sub-
ject.*

HAVING already considered the several Parts of *Mineralogy* *, as previous to the Art of *Metallurgy*, we now come to Enquire into the Operations of Metallurgy itself.

*Metallur-
gical Ope-
rations of
two kinds.*

2. These Operations are of two kinds, or smaller and larger; with regard to which the whole of Metallurgy may be divided into two Parts; viz. *Assaying*, and *Smelting*.

Assaying.

3. By Assaying we understand the Method of determining by Trial, in Miniature, what will be the Yield of an Ore in pure Metal when it comes to be wrought in the larger Furnace.

*And Smelt-
ing.*

4. And by Smelting we understand the several Ways of reducing Ores to pure Metal in the large Way of Business, so as to fit the Produce for the civil, mechanical, and oeconomical Uses.

*Design of
the Expe-
riments.*

5. We shall here enquire into both these Parts of Metallurgy, or consider as well the Smelting as the Assaying of Ores. Thus the *first* Experiment will shew the Method of Assaying and Smelting Gold and Silver; the *second* will shew the Method of separating Gold from Silver; the *third* will shew the Method of Assaying and Smelt-

* See *Lect.* XVII.

ing Copper, Tin, Lead, and Iron; the *fourth* will shew the Method of making Brass and Princes Metal; and the *fifth* will exhibit the Method of making Steel.

EXPERIMENT I.

The Method of Assaying and Smelting Gold and Silver Ores.

6. (1) We took a Penny-weight of Silver-*Silver Ore* Ore reduced to fine Powder; and having put *assayed by* it together with half an Ounce of Lead cleared of *Testing.* its Silver, into a little flat Essay-Crucible, under a Muffle, in the Testing-Furnace, we continued to Use a gentle Heat till the Lead had imbibed the powdered Ore at least its metallic Part, and separated the more stony Matter in form of a glassy *Scoria* at the Top. (2) We now took out the Lump of Lead, impregnated with the Silver of the Ore, and placed it upon a *Test*, which had been heating, or nealing, all this while under the same Muffle; and working with a proper Degree of Heat, till all the Lead was either evaporated, vitrified, or sunk into the Test, we found a little Bead, or Grain, of Silver left behind; which Grain, or Bead, being exactly weighed, and compared with the original Weight of the Ore, gives the proportion of Silver contained in the Ore, that is, determines its Richness: And the same Method is equally applicable to Gold-Ores, Sand, or any other Matters containing Gold, Silver, or a Mixture of both.

7. This Operation is usually called Testing, *The Operation* or Cupelling; and exhibits almost the whole Art *ration explained.* of the Assay-Master and Refiner. We see the Process consists of two Parts; viz. *Imbibition*, and *Separation*: For the Lead is first made to drink

drink in all the Silver from the Ore; and then the same Lead is entirely separated from the Silver. And in this Manner also are Essays taken of Silver Coin, or any Mixtures of the nobler with the ignobler Metals: For when the Operation is exactly performed, no other Metals, besides Gold and Silver, will be left upon the Test.

*Its Ratio-
nale.*

8. The physical Reason of the present Process deserves to be enquired into. The Laws or Principles on which it depends are these: (1) When the imperfect Metals, or other Minerals, are added to melted Lead, some of them will not enter into it, but remain floating on its surface, in form of a hard *Scoria*; which is the Case with Iron: (2) Others enter it, but gradually emerge again; as Tin: (3) Others totally exhale; as Regulus of Antimony, and Arsenic: (4) Others again burn to Ashes, or run into Glass, along with the Lead; as does Copper: But (5) neither Silver nor Gold is capable of flying off, burning to Ashes, or turning to Glass, by being detained in melted Lead: Whence these two Metals, of course, remain pure and separated from all the Rest, at the End of the Operation. And thus we find, that the Gold and Silver remaining all the Time mixed among the Lead, without going into Glass, continually sink down from the shelving sides of the Test, towards the Bottom of the Hollow, along with the Lead; which being at length totally consumed, and the Fire unable to keep Silver or Gold melted without some Addition of Lead, they necessarily grow rigid, and fix in a small Bead at the Centre of the Test.

*Gold and
Silver
Ores, how
treated in
the large
Way.*

9. In the large Way of Business, Silver or Gold Ores are treated either by Amalgamation with Mercury, or by Smelting and refining them with Lead. The Method by Amalgamation is used

used only where the Ore is exceeding rich; particularly at the Silver Mines of *Potosi*: For by *Amalgamation*. grinding such rich Ores with Mercury, the nobler Metals will be drunk up by it, and may be readily separated from it again by Distillation, which carries over the Quicksilver, and leaves the nobler Metals behind. Lead is used along with the poorer Ores, in order to drink up the nobler Metals they may contain; which it does much after the same Manner by Fusion, as Quicksilver does without it; so as to separate many heterogeneous Parts, by keeping them floating, and afterwards restoring the nobler Metals, by Cupellation.

10. The large Way of Smelting Gold and Silver Ores is analogous to the small one of *Assaying*. *And Fusion*. saying; all things being proportionably larger, the Fire animated with Bellows, and the Blast directed upon the Surface of the melted Metal; so as to blow off the Lead in the Form of Litharge, before it is fully vitrified. But here the Silver is not perfectly refined at one Operation; some Proportion of Lead still remaining mixed among it, that requires to be burnt out, after the same Manner, in a stronger Fire: And even thus it is with great Difficulty that Silver can be obtained pure, or totally separated, either from Lead or Copper. This large Way of working might perhaps be improved in respect of the Vessel or Test employed, and the Management of the Fire; so as to work by the Means of Flame, without the Assistance of Bellows.

11. With regard to the Test, we are to observe that Bone-Ashes, though ever so well washed and sifted, are not, perhaps, the fittest matter to make Tests of; the Tests so made being apt to crack in the Fire, unless dried very gently for many Days before they are used. But there

The larger Operation improvable in the Test.

is a particular Kind of Talc, or unvitriifiable Spath-Stone, that being calcined to fine Powder, as it readily may, and made up with a small Solution of Vitriol in Water, affords such Tests as may be immediately used without Danger of cracking.

*And the
Fire.*

12. Again; the Flame of a Wind-Furnace may be made to play upon the Surface of the melted Metal; so as readily to perform this Operation, without the Use of Bellows, which violently tear away the Silver along with the Lead, in the Form of Litharge. And this farther Convenience may be obtained, that not only smaller and cheaper Wood, but even Pit-Coal shall here serve for the Fuel; provided the Structure of the Furnace be contrived for the Purpose. And in some Places they have of late advantageously used common Pit-Coal for Testing in the large Way; and the same Improvements might also be made in the small Way of Assaying.

*Assaying
imperfect.*

13. But how improveable soever the Business of Assaying may be, it is scarce worth while to intimate in what Particulars it might be improved; because the Assay-Masters in all Countries are obliged to make their Assays in the Manner peculiar to each Country: Whence we see one Reason of the Disagreements, so frequently complained of by Merchants, in the Assays made upon the same Kinds of Ore, in *Holland, Germany, England, France, &c.* The Methods employed for this Purpose all over *Europe* are, however, in most Respects the same; but should never be trusted, unless two or three Experiments at least, made at the same Time, by the same Person, agree in the same Report.

14. And

14. And perhaps in all Natural Philosophy, *Its Difficulty.* Chemistry, and Metallurgy, there are no Experiments which require greater Skill, Accuracy, and Truth of Work, than those in the Art of Assaying, to make them fit to be depended upon: Nor indeed can such Precision as is here required be well expected, but from those who are acquainted with the rapacious Nature of many volatile mineral Fumes, and the Methods of fixing them, or preventing their carrying off the nobler Metals upon the Test. To assay in Perfection also requires a Knowledge of the Relation and Differences of all the Metals with regard to each other; and particularly to Lead and Antimony. As this Art therefore requires so much Knowledge, and so much Accuracy, in order to practise it with Success; hence, doubtless, proceeds the Difficulty we find in procuring a true Essay to be made upon any uncommon Ore: For the Art of Assaying is extremely backward in admitting of Improvements; as if it were to descend unaltered from one Generation to another.

EXPERIMENT II.

The Method of separating Gold from Silver, by Quartation.

15. We took a mixed Mass of Gold and Silver, and melting it along with three or four times its own Weight of pure Silver, we beat the whole Lump, when cold, into a thin Plate; which we put into a Glass of Proof *Aqua fortis* *, set in warm Sand; whereby the Silver was soon dissolved, and the Gold let fall in a black Powder

Gold separated from Silver by Aqua fortis.

* See *Let. VI. Exp. VI.*

to the Bottom. The Solution of Silver we now carefully poured off, and adding a little fresh *Aqua fortis* to the Gold, we used a somewhat stronger Heat than before, in order to dissolve any remains of Silver from amongst the Gold-Powder. Then the *Aqua fortis* being again decanted, we washed the Gold well, in several Parcels of fair Water. And now the Gold-Powder was put into a little Say-Cup, and placed under the Muffle in the Testing-Furnace till it became yellow. It might otherwise have been melted with Borax; which brings it to its true Colour and Form. We afterwards weighed the Gold, to determine the Proportion it bore to the Silver. Lastly, we precipitated the Silver out of the *Aqua fortis*, by suspending a Copper-Plate therein; then washed the Calx, and reduced it to its metalline Form in the same Manner.

Ratio-
nale.

16. The Reason for adding three or four Times the Quantity of Silver, in Proportion to the mixed Mass, is, for fear the Mass should contain too much Gold to be fit for the Operation; or to spread the Gold contained in the Mass, and diffuse it so thinly, that it may not defend the Silver, as it otherwise would do, from the action of the *Aqua fortis*. And from the proportion of this Addition it seems to be that the Operation is called *Quartation*.

The
Trouble
and Ex-
pence of the
Operation.

17. This Method of separating Gold and Silver was unknown to the Ancients; who therefore separated Silver from Gold by Calcination; and so lost all the Silver that was mixed with the Gold. And indeed the Method by *Quartation* is expensive and laborious; so as not to be very advantageously practised in the large Way of Business; though the whole has been divided into such a Number of Hands, as to make the several Parts come cheap: some Operators being wholly

wholly employed in making the *Aqua fortis*; others in purifying it, or bringing it to *Proof*; others in laminating the Silver, and dissolving it; others in separating and reducing the Calx of the Gold; others in precipitating the Silver with Copper; and others again in separating the Copper from the *Aqua fortis*. And thus the whole Operation has been found to answer, so long as about a Dram of Gold could be recovered from a Pound of Silver.

18. But there are certain Workmen of late, *The Operation improved, or superseded.* who have a Method of separating Gold from Silver to much greater Profit, without the Use of *Aqua fortis*, or *Aqua regia*; and that barely by a dexterous Application or Management of the Fire; at least without any costly Additions. This Method is kept as a Secret, but may, perhaps, be no other than that published by M. Homberg *a)*; which consists in fluxing the mixed Mass of Gold and Silver with equal Parts of rough Nitre and decrepitated Salt, placed at the Bottom, of the Melting-Pot. By this means the Operation, in the large Way, may be finished in a Quarter of an Hour, the Gold falling to the Bottom, and leaving the Silver suspended or detained in the Salts. Another Way of effecting this Separation may depend upon a dexterous Use of Sulphur, which has the Power of making Silver melt away from a metalline Mixture almost as easy as Lead *b)*.

19. But to obtain either Gold or Silver in absolute Purity is no easy Task. For the common Uses, indeed, the Methods above delivered may serve; but for the more curious chemical and philosophical Purposes, better Ways than

a) In the French Memoirs.

b) See below § 20.

are commonly known and practised should be discovered. To refine Gold by melting and testing it with Antimony, or Glass of Antimony, is generally, and even by the metallurgical Chemists, thought a perfect Way; but M. *Homburg* * has shewn, that even this Criterion, as also Quotation, Cupelling with Lead, Fluxing with Borax, &c. may fail, in Case the Gold be mixed with *Emery*, or possibly some other things. When Gold is *eager*, as the Workmen call it, that is, brittle, they hold it as a Secret to melt it with Mercury-Sublimate. But perhaps no Gold can be proved to be perfectly pure, till it has gone through all the trials hitherto known; or even some of a more curious Nature; particularly melting with crude Antimony, and afterwards cupelling the Regulus with Lead; and at last, fusing it with Borax. Which Process we recommend to those who require Gold in absolute Purity for any Standard, or very curious Operation.

*Silver,
how.*

20. The Methods of obtaining Silver in Purity are various, and differ according to the Metal wherewith the Silver is mixed or alloyed. If Copper be the Alloy, the best and cheapest Way to purify the Silver is, to calcine it with half its Weight of common Sulphur; then melt the whole together; and throw into the Pot, at several Times a due Quantity of clean and new Filings of Iron, which will immediately draw the Sulphur from the Silver, and Form a *Scoria* at top, leaving the Silver free from Copper, Iron, or Sulphur at the Bottom.

* See the *French Memoirs*.

EXPERIMENT III.

The general Method of Assaying and Smelting the impurer Metals; Copper, Tin, Lead, and Iron.

21. We took four Ounces of Lead-Ore reduced to Powder, and mixing it with an Ounce of the clean Filings of pure Iron, and half an Ounce of the Black Flux *, we melted them all together in a new Crucible set in a Wind-Furnace. By this Means we found the Lead clearly separated, in a Lump, at the Bottom of the Crucible, after it was taken out of the Fire and suffered to cool. *Lead-Ore assayed.*

22. The Method of thus working in Crucibles, and by the Help of Fluxes, is not only too small, but also too chargeable, to answer in the large Way of Business: Nor is there any Occasion for being confined to this Method; since Fusion in a naked Fire, or in Contact with the burning Fewel, is found to act as a powerful Flux, and get the Metal out of its Ore with Advantage. Hence we every where find that Metals are smelted in open Furnaces with a naked Fire. And though this hath long been a general Practice, the physical Reason of it seems little known; insomuch that nothing is found more wanting in Philosophical Metallurgy, than the particular *History of common Fusion.* *How smelted in the open Fire.*

23. The Ores of Lead, Tin, Copper, and Iron, are all commonly fused in Contact with the Fewel of the Furnace; the prepared Ore being at first stratified, or intermixed with the Wood or Coals: Nor could these Ores be any other Way fused in a large Quantity, so as *The Ratio.*

* See *Let. I. Exp. II.*

to acquire a metalline Form, though urged with ever so strong a Flame, or beat ever so violently upon by the Fire, while kept from touching the Coals, by being included in a large Crucible, or Melting Pot, after the Manner that Glass is made ; or without adding some Flux-Powder, of an oily or inflammable Nature *a*). Even if the Ore thus treated were rich, or naturally contained some visible Grains of pure Metal, this Metal would only remain in almost the same State as it was, without enlarging its bulk from the Rest of the Ore : Whereas if a little powdered Charcoal be thrown in, or the Ores be committed to a naked Wood-Fire, they presently resolve into Metal.

The metallic Nature how preserved, or recovered.

24. We might observe in our Experiment of Cupellation *b*), how extremely apt these imperfect Metals are to receive a destructive Alteration in the Fire, or to be burnt and reduced to Ashes, or Glass, along with the Lead ; on which Disposition of theirs the Art of Cupelling depends. But by contriving to melt these Metals in Contact with the Coals, their metallic Form is greatly preserved ; especially as the stony, vitrifiable Matter, wherewith such Ores are usually mixed, occasions them, by their clinging Nature, to unite more intimately with the glowing Coals.

Metalline Calces reduced.

25. This Doctrine receives a remarkable Confirmation from the usual Method of recovering Metals burnt to Ashes at the Smelting Furnace : For if the Litharge, blown off in testing, or even the Glass of Lead, or the Ashes of any other of the imperfect Metals, be barely melted in Contact with Charcoal, they presently recover their metalline Form. And the same Thing

a) See *Lect. II. passim.*

b) See *Exp. I.*

is likewise effected by the Addition of any unctuous or inflammable Matter; whence it seems to be the unctuous or inflammable Matter of the Coals, which thus insinuating into the metalline Calces, restores their metallic Nature. And we have several Times, in the Course of these Lectures, had Occasion to observe the great Affinity there is betwixt Oils and Metals*; insomuch that their true metallic Form, or their Softness and Ductility, seems entirely owing thereto.

26. There are three Things, therefore, to be principally regarded in the Smelting of Ores; viz. (1) the Fusibility of the Metal; (2) the Fusibility of the Scoria; and (3) the Contact or Mixture of the metallic Matter with the inflammable Part of the Coals. *Three things to be regarded in Fusion;*

27. (1) Different Metals run in different Manners from their Ores. Thus Lead, though extremely fusible in the Metal, yet runs with Difficulty from the Ore; so as to require a considerable Violence of Fire. This Stubbornness, not belonging to the Metal, must be attributed to the stony, sulphureous, or other mineral Matter, wherewith the Ore is mixed; which Matter seems to require a Degree of Heat capable of vitrifying the Lead, before the Metal will run: But then the Lead thus vitrified recovers a metallic Form again, by coming in Contact with the Coals. *viz. The Fusibility of the Metal: Instances in Lead.*

28. In the Case of our present Experiment, the Iron-Filings laying hold of the sulphureous Parts of the Ore, leave the Lead at Liberty to run much sooner, and freer, from the Stone: Where also the great Degree of Heat communicated by the Iron-Filings, and their inflammable Nature, must have a considerable Effect, at the

* See *Leç. VI. Exp. II. & alibi passim.*

same Time that they will not incorporate with Lead, but float on its Surface in Fusion.

*Tin, Cop-
per, and
Iron.*

29. Tin runs from its Ore with greater Ease than Lead; and is therefore smelted in much less Furnaces: But Copper requires an intense Heat, or a Blast-Furnace; and Iron, the greatest Heat that can be given in a Furnace: and both Iron and Copper absolutely require immediate Contact with the Fuel employed. Hence it appears, that each Metal must have its determinate Degree of Heat, to run it with Advantage from the Ore or Stone.

*The Fusibi-
lity of the
Slag.*

30. (2) In order, likewise, to obtain the Metal from the Ore to best Advantage, the *Scoria*, or Slag, must be necessarily made to run thin and fluid; otherwise it entangles or inviscates the Metal, and will not let it separate fully. And hence we frequently observe, in the Assaying of Copper Ores, small grains of Metal interspersed, here and there, among the *Scoria*, that require to be separated by stamping and washing the whole Mass; which Labour might have been prevented, by using a suitable Flux, and a proper Degree of Heat, capable of procuring a thin Fusion; so as to have made all the Metal fall to the Bottom of the Crucible, which it constantly does when the Operation is well performed.

31. To promote a thin Fusion of the Slag, in the larger Furnace, it is often proper to use the more soft and fusible Sands as a Flux; and sometimes that Loamy Sand, which the Smiths employ for the Welding of Iron; this Sand readily vitrifying, and adhering to the Metal in the Fire: And where it will answer the Charge, even Litharge, or Dross of Lead, might be used for this Purpose, in the larger Furnaces; for scarce any Thing procures so thin a Fusion of the Slag.

32. In the large Work, Sulphur is found to adhere tenaciously to Copper; which Metal, therefore, seldom comes out pure in the Furnace, without repeated Fusions. The best Method of separating this Sulphur is, to use a violent Heat, no additional Flux at all, and the greatest Draught of Air that can any Way be procured; so that all Things may conspire to burn out, or carry off, the Sulphur, and introduce, in its Stead, a Thing of a different Nature; viz. the inflammable Matter of the Coals; on which, as we before observed, Ductility seems to depend. But where Iron is mixed with Copper, no better Addition is found than Sulphur, and the more sulphureous Marcasites; or what at the Smelting Huts they call *Marcasite Blocks*: For the Sulphur which these contain causes the Copper readily to run away from the Iron, and leave it behind in the Furnace. And here the Power which Sulphur has upon the several Metals is very remarkable. We before observed, that it renders Silver almost as fusible as Lead*: It also greatly increases the Fusibility of Iron, and Regulus of Antimony; but renders Tin much less fusible than it is of itself; and Lead, even refractory in the Fire: Whence certain Rules might be formed, for the Use and Application of Sulphur to Metals, for the Improvement of Metallurgy. And thus the whole Art of Smelting seems to depend upon knowing the Degree of Heat required by every Ore; so as to make the Slag, as well as the Metal, run thin, and evaporate or discharge the sulphureous Parts; and, lastly, to introduce the proper

* Exp. II. §. 18.

metallic, ductile Form, by Means of an unctuous or inflammable Matter.

Consequences of artificial Fusions and Separations.

33. It seems principally owing to a Defect in the Knowledge of Fusion, that so many Recrements, or Slags, of Metals, anciently thrown, as useless, from the Furnace, have been wrought to considerable Profit of late, by more skilful Workmen; at least it seems more rational to attribute the Success to this Cause, than to any supposed Growth of Metals in such Slags: So likewise it is currently believed, that Lead grows rich in Silver, by lying exposed to the open Air, or by long covering Churches, or other Buildings; whilst perhaps it is rather owing to the Unskilfulness of the former Workmen, who were not able to separate all the Silver naturally contained in Lead. And thus it appears certain, that the ancient Metallurgists were unacquainted with any Way of extracting, to profit, a small Quantity of Silver out of Copper; which is now commonly done by an ingenious Contrivance*: Whence the ancient Copper found upon Temples, or other Buildings, frequently contains silver. So likewise in the *Forest of Dean* they at this Day work the Slag of their old Iron-Works over again to Profit.

Metals to be carefully cooled.

34. All Moisture, as well as too sudden Cooling, proves prejudicial to the more ignoble Metals after Fusion; and sometimes dangerous to the Operator. A little Water falling upon melted Iron or Copper makes them expand with prodigious Violence, and discharge themselves abroad with a Force like that of a Canon: And even sudden cooling will often occasion the Surface of the Metal to crack, and force the more internal Part, not yet set or fixed, to issue out to

* See below, §. 35.

a considerable Distance; whence either Loss of the Metal or Mischief may ensue. But to prevent these ill Effects, after Cupellation, it is usual for the Operator to throw a Quantity of Water, all at once, upon the Lump of Silver, as it lies in the Test, at the Moment that it begins to grow rigid; for thus the Water, by its Coldness, suddenly makes so thick a Cover upon the Surface of the Silver, that the hotter inside Parts cannot break through the upper: Whence that springing, or spouting out, of the Silver, which we sometimes see in the smaller Way of assaying upon the Test, when the Metal spontaneously cools, is entirely prevented.

35. We have already considered how Gold and Silver are to be separated when mixed *a)*; *The igno- bler Metals how sepa- rated from each other;* we should also know how the less noble Metals may be separated from one another: This is done either by Means of Fire alone, or by Means of Lead. Thus Copper, being more fusible *viz. Iron from Cop- per.* than Iron, will, in a proper Furnace, melt, and run entirely from it; whilst the Iron is not made to flow with the same Degree of Heat as melts the Copper, or else sticks behind in the Slag. After the same Manner Lead, being *Lead from Copper.* more fusible than Copper, readily runs away from it, in a Furnace kept of a due Heat for the Purpose. A Mixture of Iron and Lead is separated in the same manner; the Iron floating *Iron from Lead.* upon the Surface of the Lead. Copper, Tin, Iron, Antimony, &c. we before observed might be separated from Gold or Silver, by testing with Lead *b)*; but then the ignobler Metals are lost. And where only a small Proportion of Silver is mixed with a large one of Copper, this Method would prove useless, or prejudicial:

a) See Exp. II.

b) Exp. I.

D d 4

Nor

408 LECTURE THE EIGHTEENTH.

*Silver
from Cop-
per.*

Nor can a small Proportion of Silver be well separated from Copper, by any Method hitherto known; so as to preserve the Copper pure, or easily recoverable: Whence at the Smelting-Huts the Method is, to get the Silver out of imperfect Copper, whilst it still remains mixed with its own Sulphur, under the Form of what they call *Black Copper*. This they melt, and make to run among a large Proportion of melted Lead; then casting the Mixture out into large Blocks, these are carried to a particular Furnace, and there set upright, so as that the Fire, being lighted at top, may commodiously play between them. And thus the Lead melts away from the Blocks, carrying with it the Silver before contained in the Copper; the Blocks of which Metal are now left hollow, porous, spongy, and wrinkled. These exhausted Blocks are then removed to a hotter Furnace, in order to be farther drained of their Lead. The last Remains are now, in another Furnace, reduced to perfect Copper; and the whole Parcel of Lead, thus enriched, committed to the Test, in order to separate the Silver.

*Copper Ore
tested*

36. In the same Manner may Copper Ores be assayed, by testing them with a smaller Proportion of Lead than is used to Silver Ores; tho' this Operation requires a great Degree of Care and Exactness, to prevent the Copper from being carried off with the Lead, or vitrified. So likewise when Copper happens to be mixed with Iron, the best Method of separating them, in the Way of Essay, is to melt them with Lead; which readily imbibes the Copper, but throws the Iron to the Surface; where being entangled with the vitrified *Scoria* of the Lead, it may be taken off, and the Copper thus brought to a great Degree of Purity; though indeed it is apt

to lose a little of its Ductility, on Account of some very minute Proportion of Lead, or its Fumes, remaining therein.

37. We have not here confined ourselves to the Consideration of one Metal more than another; but endeavoured, under the present Experiment, to shew the Ways of treating all the ignobler Kinds, or working them, in the best Manner, from their Ores. It is easy to apply this general Doctrine, occasionally, to the Treatment either of Lead, Tin, Copper, or Iron. *The Doctrine general.*

EXPERIMENT IV.

The Method of making Prince's Metal.

38. We took six Ounces of Copper, and melted it in a Wind-Furnace, added to it an Ounce of Zink; then stirring the whole well together, we immediately poured out the Metal. The Copper and the Zink may be put into the Crucible together, if first covered over with the Black Flux; which prevents the Avolation of the Zink, or preserves its metalline Form. *A mixed Metal of Copper and Zink.*

39. This is an expeditious Method of making a fine Kind of Brass; whereas the common Method with *Lapis Calaminaris* requires a considerable Length of Time, and a violent Fire: For this Purpose they calcine and powder the Calamy; then mix it with a little Charcoal-dust; and to seven Pounds of this Mixture add five of Copper-Plates; then giving eleven or twelve Hours Fire, the Copper imbibes about one third of its Weight of the Calamy. *Brass how made.*

40. It is here remarkable that the Calamy, though no compleat metallic Body, nor malleable, should yet concrete along with the Copper, so as not only to increase its Weight, but also to extend *The Nature of Calamy.*

extend with it under the Hammer; which Zink, in making the Prince's Metal, does not do, though it appear in all Respects of a more metallic Nature than Calamy.

And Zink. 41. The Agreements and Disagreements of these two Bodies, Zink and *Lapis Calaminaris*, may deserve to be farther enquired into, by particular Experiments. The Inflammability of Zink is very remarkable; for it burns durably of a bluish white Flame in the Fire; and thus resolves into a white Calx.

Imitations of Gold. 42. Many curious Phænomena, and unexpected Results, happen upon mixing metallic and mineral Bodies in the Fire; all which deserve to be tried, and noted, as Facts that might at least direct to the discovery of several new and useful Mixtures, or Compositions of Metals. We might be encouraged to prosecute this Enquiry, by those pretty Imitations of Gold, lately introduced for the making of Watches, Buckles, Cane-heads, Snuff-boxes, &c. But perhaps a better Imitation of Gold, for these and many other Purposes, may be obtained by M. *Homburg's* Method of treating Copper with Quicksilver: For if an Amalgam be made of one Part pure Copper, and three Parts Quicksilver; and the Amalgam be boiled in River-Water for two Hours; then the Quicksilver distilled off, and cohobated once; the remaining Copper, being now fused, will be found of a beautiful Gold Colour, and more ductile than common Copper; so as to become well fitted for Watch-work, Gilding, and the finer Machines and Utensils.

Homburg's Metal.

EXPERIMENT V.

The Method of converting Iron into Steel.

43. We took a few Pieces of soft Iron-Wire, *Steelmade.* and burying them in a close Crucible, full of powdered Charcoal, set the whole in a Wind-Furnace, for two or three Hours; then taking out the Pieces of Wire we found them changed to Steel.

44. The Method of making Steel has been *The ancient Method.* usually kept as a Secret, and at present there are but very few Steel-makers in *England*: The ancient Method was, to keep slender Bars of Iron ignited, for several Hours, in a melted Mixture of Iron and vitrescible Sand; then taking out the Bars, forging them, and immediately plunging them, whilst hot, into cold Water; afterwards forging them again, till they would easily snap, and appear white, and of a close Texture, or Steel-Grain, when broke.

45. The present Method is, to stratify a large *The modern Method.* Number of slender Iron Bars with powdered Charcoal; to fill a Furnace with them, in the Form of a long Chest; and then to keep up a strong Fire, but so as not to melt the Iron, for two or three Days together. And thus at length, when the Furnace is cold, the Bars are taken out unaltered in their external Form: But they may be blistered according to the Pleasure of the Operator, by using Quicklime along with the powdered Charcoal.

46. The whole Secret of making Steel seems *On what the Operation depends.* to depend upon excluding the Air from the Iron to be wrought upon. Accordingly if a large Ball of Iron be kept so hot, for some Time, that its external Surface shall melt, and run like Water,

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Water, the internal Part of the Ball will, at the same Time, be converted into true Steel. And hence appears the Reason why certain Knots, or Spindles, of Iron are sometimes found in the Middle of Cast Work, so hard that no Tool will touch them.

Case-hardening.

47. The Art of Case-hardening is a lesser Degree of Steel-making; and is practised by baking Razors, Files, Knife-Blades, &c. in a Kind of Oven, stratified with powdered Charcoal, Hoofs, Horns, and the like, so as to exclude the Air; and thus, by baking, to give a Coat of Steel to Instruments, some Depth below their Surface.

The best Steel, how made.

48. But the Making of the best Steel depends upon the Nature of the Iron employed, or its Ore; and usually requires a proper Mixture of several Kinds together, as well as Perfection in the Art of Tempering; which, according as it is managed, suits the Steel for different Uses. Thus Gravers are of one Temper, Drills of another, Watch-Springs of another, Razors of another, &c. Which Tempers are given them by being quenched with different Heats in Tallow, Water, or certain Liquors, Juices, or the like.

AXIOMS and CANONS.

1. We learn from the foregoing Enquiry, That different mineral and metallic Matters bear different Relations to melted Lead in Fusion: Whence some of them will not mix therewith, but float on its Surface; others evaporate, and others vitrify with it; whilst Silver and Gold remain unaltered by it, and unimpaired*.

2. That the nobler Metals have nearly the same Relation to Quicksilver, as they have to

* Exp. I.

melted

melted Lead; being readily drunk up by them both, and thus separated from other heterogeneous Matters *a*).

3. That Testing, in the large Way, is improvable by finding a properer Matter than Bone-Ashes for the making of Tests; by working without Bellows; and again by using Pit-Coal, and a well contrived Furnace *a*).

4. That the Art of Assaying is hitherto imperfect; but capable of receiving considerable Improvements from chemical and mechanical Knowledge *a*).

5. That the troublesome and expensive Method of separating Gold from Silver by *Quartation*, may be advantageously superseded, or set aside, by Means of Fusion, or a dexterous Management of the Fire *b*).

6. That Gold and Silver are rarely rendered absolutely pure, or separated from all other Kinds of metallic or mineral Matters; and that to purify them to such a Degree requires the Use of better Methods than those commonly employed: though the Thing is still performable by Art, and a suitable Process *b*).

7. That the particular *History of common metallic Fusion* is wanting, for the Improvement of Metallurgy *c*).

8. That when the Ore of an imperfect Metal is in immediate Contact with the Fire or Fuel, it yields more and better Metal, than when contained in a Crucible, or kept from touching the Coals *c*).

9. That a languid Fire lessens the Yield of an Ore; but a brisk one, if not too long continued, increases it *d*).

a) Exp. I. *b*) Exp. II. *c*) Exp. III. *d*) Ibid.
See also *Lect. XVII.*

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10. That the Business of Smelting in Perfection depends (1) upon using a Degree of Fire suited to the Ore; (2) procuring a quick and thin Fusion of the *Scoria*; and (3) a close Contact of the Metal with the Fuel, or Coals, employed *a*).

11. That Sulphur has different Effects upon the different Metals; which Effects being well noted, Rules of Practice might be thence derived, for the farther Improvement of Metallurgy *a*).

12. That metalline Recrements, or the Slags of Metals once smelted, have been wrought over again to profit, on Account of the imperfect Manner wherein the Ores were originally treated for their Metals *a*).

13. That the ignobler Metals are separable from each other by the Application of proper Degrees of Heat; so as to make the more fusible melt away from the less fusible; at least with the Assistance of Lead *a*).

14. That all Metals are reducible, by burning, or Calcination, to terrestrial Powders, or *Calces*; which, by being melted with any inflammable Matter, assume their metalline Form again *a*).

15. That the great Enemies to Ductility, or the true metallic Nature, are Sulphur, Cobalt, and Things compounded thereof *b*); but that all unctuous or inflammable Bodies are friendly to Metals, and promote or restore their Ductility, when melted therewith *c*).

16. That Copper may be made to approach the Colour of Gold, and at the same Time not lose, but increase, its Ductility, by being amalgamated with, and distilled from, Quicksilver;

a) Exp. III. *b*) Exp. III. See also *Let. XVII.* *c*) Exp. III.

and that probably many artificial or compound Metals are discoverable, by mixing various metalline and mineral Bodies together; so as greatly to enrich and improve the Art of Metallurgy *a*).

17. That Steel is made by a proper Application of Fire to Iron, in a close Place, so as to prevent the open Air from communicating freely with the Iron *b*).

18. That Metals receive particular Alterations in their Texture or Consistence, according to the Nature of the solid Substance or Liquor, wherein they are quenched or cooled *b*).

19. That, in general, Ores are no more than a natural, loose Mixture of metallic Matters, along with earthy and sulphureous ones: Whence artificial Ores may be readily made, by calcining a Metal with Sulphur, and mixing it with Earth; so as, with Heat, to form solid Lumps of Ore, resembling those Dug out of Mines *c*).

20. That numerous Experiments remain to be made, Facts of Nature, or Observations, to be registered, and Relations of Bodies to be found, before this useful Subject of Metallurgy can be brought to Perfection *d*).

a) Exp. IV. *b*) Exp. V. *c*) See Lect. XVII. and XVIII. *passim*. *d*) Exp. I. II. III. IV. V.

LECTURE XIX.

CONTAINING

PYROTECHNY; or *Experiments relating to*
Gunpowder, Explosions, and Phosphori.

The Design. I. **T**HE present Design is to enquire into the Nature of Gunpowder, Explosions, and *Phosphori*; and to try if any useful Doctrine or Discoveries may be thence derived, for the Improvement of Chemistry and Natural Philosophy. We therefore propose (1) to examine into the Nature and Composition of Gunpowder, with the Ways of trying and improving it; (2) to shew some of the more remarkable Kinds of Explosions; (3) to examine some of the more eminent *Phosphori*; and (4) to deliver the Doctrine pointed out by this Kind of Experiments.

The Intent of the Experiments. 2. Our *first* Experiment, therefore, will shew the Method of making Gunpowder; our *second* the Method of making the *Pulvis* and *Aurum fulminans*; our *third*, a Method of producing Heat and Fire by the Mixture of Sulphur and Iron Filings; our *fourth*, a Method of producing Coruscations with Oil of Vitriol and Iron Filings; our *fifth*, a Method of producing Fire and Flame by the Mixture of two cold Liquors; and our *sixth* Experiment will shew the Method of making the liquid Phosphorus of Urine.

EXPERI-

EXPERIMENT I.

The Method of making Gunpowder.

1. We took four Ounces of refined Salt-Petre, *Gunpow-*
an Ounce of Brimstone, and six Drams of *der made.*
Small-Coal; these we reduced to fine Powder,
and continued beating them, for some Time,
in a Stone-Mortar, with a Wooden Pestle;
wetting the Mixture, between whiles, with Wa-
ter, so as to bring the whole into an uniform
Paste; which we then reduced to Grains, by
passing it through a Wire-Sieve fit for the Pur-
pose: And in this Form, being carefully dried,
it became the common Gunpowder.

2. We formerly shewed the Way of refining *Vitre how*
Salt-Petre for the making of Gunpowder *. In *pulverized*
order to reduce this Salt to Powder, they dis- *readily.*
solve a large Quantity of it in as small a Propor-
tion of Water as possible; then keeping it con-
tinually stirring over the Fire, till the Water
exhales, a white dry Powder is left behind.

3. In order to purify the Brimstone employed, *The Sul-*
they dissolve it with a very gentle Heat; then *phur puri-*
scum and pass it through a double Strainer. If *fied.*
the Brimstone should happen to take Fire in the
melting, they have an Iron-Cover that fits on
close to the melting Vessel, and damps the
Flame. The Brimstone is judged to be suffi-
ciently refined, if being put between two hot Iron
Plates, it melts into a Kind of red Substance,
without yielding any fetid Odour.

4. The Coal for the making of Gunpowder, *The Coal*
is either of Willow or Hazel, well charred *prepared.*
in the usual Manner, and reduced to Powder:
And thus the Ingredients are prepared for mak-

* See *Let.* XIII.

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TheStamp- ing. ing this Commodity. But as these Ingredients require to be intimately mixed, and as there would be Danger of their firing if beat in a dry Form, the Method is to keep them continually moist, either with Water, Urine, or a Solution of Sal-Ammoniac, and to continue thus stamping them together for 24 Hours; after which the Mass is fit for corning, and drying in the Sun or otherwise, so as sedulously to prevent its firing.

Rationale of Gun- powder.

5. The explosive Force of Gunpowder is now a thing commonly known; but the physical Reason thereof may not, perhaps, be hitherto sufficiently understood. In order to explain it, let us observe (1) that Salt-Petre, of itself, is not inflammable; and though it melts in the Fire, and grows red hot, yet it does not explode, unless it comes in immediate Contact with the Coals; (2) that Brimstone easily melts at the Fire, and than readily catches Flame; (3) that powdered Charcoal readily takes Fire, even from the Sparks yielded by a Flint and Steel; (4) that if Nitre be mixed with powdered Charcoal, and brought in Contact with the Fire, it burns and flames; (5) that if Sulphur be mixed with powdered Charcoal, and Fire applied to it, part of the Sulphur burns slowly away, but not much of the Charcoal; and (6) that if a lighted Coal be applied to a Mixture of Nitre and Sulphur, the Sulphur presently takes Fire, with some Degree of Explosion, leaving a Part of the Nitre behind; as we see in making the *Sal Prunella* and *Sal Polychrestum*.

6. These Experiments duly considered may give us the chemical Cause of the strange explosive Force of Gunpowder: For each Grain of this Powder consisting of a certain Proportion of Sulphur, Nitre, and Coal, the Coal presently

ly takes Fire, upon Contact of the smallest Spark; whereupon both the Sulphur and the Nitre immediately melt, by Means of the Coal interposed between them, and burst into Flame; which, spreading from Grain to Grain, propagates the same Effect almost instantaneously; so that the whole Mass of Powder comes to be fired: And as Nitre contains a large Proportion both of Air and Water, which are now violently rarefied by the Heat, a Kind of fiery explosive Blast is thus produced; wherein the Nitre seems, by its aqueous and aerial Parts, to act as Bellows to the other inflammable Bodies, Sulphur and Coal, blow them into a Flame, and carry off their whole Substance in Smoak and Vapour.

7. The Discovery of this Composition was accidental, and perhaps owing to that common Operation of fulminating Nitre with Sulphur, for the making of *Sal Prunellæ*. It appears to have been known long before the Time of *Schwartz*, as being particularly mentioned by *Friar Bacon*. *Its Discovery.*

8. The three Ingredients of Gunpowder are mixed in various Proportions, according as the Powder is intended for Musquets, Great Guns, or Mortars: Though these Proportions seem not to be hitherto perfectly adjusted, or settled by competent Experience. *The Ingredients differently proportioned.*

9. There are two general Methods of examining Gunpowder; one with regard to its Purity, the other with regard to its Strength. Its Purity is known, by laying two or three little Heaps near each other upon white Paper, and firing one of them; for if this takes Fire readily, and the Smoke rises upright, without leaving any Dross or feculent Matter behind, and without burning the Paper, or firing the other Heaps, it is esteemed a Sign that the Sulphur and Nitre *How tried as to purity.*

were well purified; that the Coal was good; and all the three Ingredients were thoroughly incorporated together. But if the other Heaps also take Fire at the same Time, it is presumed that either common Salt was mixed with the Nitre, or that the Coal was not well ground, or the whole Mass not well beat and mixed together; and if the Nitre or Sulphur was not well purified, the Paper will be black or spotted.

*How as to
Strength.*

10. In order to try the Strength of Gunpowder, there are two Kinds of Instruments in Use; but neither of them appear more exact than the common Method of trying to what Distance a certain Weight of Powder will throw a Ball from a Musquet.

*How
strengthened.*

11. To increase the Strength of Powder, it seems proper to make the Grains considerably large, and to have it well sifted from the small Dust. We see that Gunpowder reduced to Dust has little explosive Force; but when the Grains are large, the Flame of one Grain has a ready Passage to another; so that the whole Parcel may thus take Fire nearly at the same Time; otherwise much Force may be lost, or many of the Grains go away, as Shot, unfired.

12. It should also seem, that there are other Ways of increasing the Strength of Powder; particularly by the Mixture of Salt of Tartar: But perhaps it may be improper to divulge any Thing of this Kind, as Gunpowder seems already sufficiently destructive.

*White
Powder.*

13. There has been much talk of a *white Powder*; which, if it answered the Character given it, might be a dangerous Thing: For 'tis pretended that this white Powder will throw a Ball as far as the Black, yet without making any Report. But none of the white Powder which we have

have seen answers this Character; being, as we apprehend, commonly made either with Touch-wood or Camphire, instead of Coal. The most dangerous white Powder, if it may be so called, is condensed Air; which, though able to discharge a Ball, with great Force, to a considerable Distance, makes not a loud Report; especially when not violently condensed, as it need not be to have pernicious Effects.

14. And how far Wind-Guns are improve-^{Wind-Guns.} able, has not, perhaps, been well considered. Some of them we have seen discharge a great Number of Bullets successively; even the last whereof would go through an Inch-Plank, at the Distance of several Yards: So that this Machine might answer the same End as a Musquet. But whether it be practicable to make great Guns in the same Manner, is another Consideration; and chiefly depends upon finding a Spring sufficiently strong to resist the violent Force wherewith Air might be condensed by the Use of a Winch, &c.

EXPERIMENT II.

The Pulvis and Aurum fulminans prepared.

15. We took three Ounces of purified Nitre, ^{Pulvis ful-} two Ounces of Salt of Tartar, and one Ounce ^{minans} of Brimstone, and ground them well together ^{prepared.} in a Mortar; then putting a small Quantity, as about half a Dram, of this Powder upon an Iron Plate, and placing it over a gentle Fire, as soon as the Powder just began to melt, it made a smart and loud Explosion.

16. The most philosophical Way of accounting ^{its Effect} for this Effect of the *Pulvis fulminans*, is by sup-^{accounted} posing that the acid Spirits of the Nitre and ^{for.}

E e 3

Sulphur

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Sulphur, being loosened by the Heat, rush towards one another, and towards the Salt of Tartar, with so great a Violence, as, by the Shock, at once to turn the whole into Vapour and Fume.

Aurum fulminans prepared.

17. We dissolved a few Grains of fine Gold in *Aqua-Regia*, precipitated the Solution with Salt of Tartar, and thus obtained a Powder, which we dried with a very gentle Heat. A single Grain of this Powder being laid upon the point of a Knife, and held over a lighted Candle, presently went off, with a very brisk and loud Report.

Its odd Properties.

18. This *Aurum fulminans* has other remarkable Properties; for (1) it does not, like the *Pulvis fulminans* and Gunpowder, require the Application of actual Fire to make it explode; but though prepared with two of the most fixed Bodies, Gold and Salt of Tartar, yet is so volatile as to fly off, and give this loud Report, with a less Degree of Heat than suffices to kindle any of the most inflammable Bodies; or even by being strongly rubbed in a Mortar, or dried on a hot Furnace: (2) It exerts its explosive Force *in vacuo*, as well as in the open Air; and when made to explode in the exhausted Receiver, a fine Gold Dust has been found sticking to the Sides of the Glass. (3) The Addition of a little Brimstone to this Powder takes away its fulminating Property; so that after having been melted therewith, the Gold is set loose, and may be easily recovered, in its native form, by fluxing it with Borax.

The Rationale.

19. Hence it should seem that the Body of the Gold in this Powder is subtilly divided by the Action and Interposition of the Parts of the compound Menstruum; which Menstruum being of
an

an aqueous and aerial Nature, and its Parts closely wedged in betwixt the fine ponderous Parts of the Gold in the *Aurum fulminans*, when this Powder comes, any way, to feel such a Degree of Heat as suffices strongly to rarify and expand the aqueous and aerial Particles, they burst with Violence from their Prisons, and scatter the dusty Particles of the Gold around.

EXPERIMENT III.

The Production of Heat and Fire, by the Mixture of Sulphur and Iron Filings.

20. We took two Pounds of clean Iron-Filings, and as much common Brimstone, and beating them together for some Time, in a Mortar, with the Addition of Water, we brought the whole to a Kind of Paste; which being close prest into an earthen Pot, and set in a Chimney, it in a short Time begun to grow hot, and at Length took fire.

The firing Mixture of Iron and Sulphur explained.

21. This Mixture never fails to take Fire, if the Quantity be large; but if it be small, the Paste only heats and cracks, in several Places, so that hot Vapours issue out thereat. But if the Heat continues sufficiently long, the whole Mass will be changed into one uniform Substance; which, being ground and boiled in Water, affords good Vitriol of Iron*: Whence it is manifest, that the Acid naturally contained in the Brimstone enters the Body of the Iron, and dissolves it. This Action may therefore be the Cause of the Effect; especially if we consider that Sulphur consists of an unctuous or inflam-

* See below §. 26.

mable, as well as an acid Part : For this inflammable Part of the Sulphur, doubtless, takes Fire in the violent Conflict betwixt the Iron and the Acid of the Sulphur.

And applied.

22. This Experiment, if duly attended to and applied, may, in the usual Way of Philosophers, account for several Phænomena of Nature ; such as burning Mountains, subterraneous Fires, Earthquakes, hot Baths, &c. Thus, for instance, as there are large Quantities of Iron-Stone, and Sulphur, found in the Bowels of the Earth ; as also Marcasites, which are a Mixture of the two ; when these come to be wet, as they may, on many Occasions, with Water, 'tis easy to conceive, that they must heat, swell, ferment, explode, and yield a hot Steam or Vapour, which forcing its Way through certain Caverns of the Earth, shall produce Earthquakes, or violent Strugglings, of longer or shorter Duration, till the Force finds vent, or expires through some Cranny into the Atmosphere. Sulphureous Vapours certainly abound in the Bowels of the Earth, and ferment, and conflict with Minerals, so as to take Fire, and make sudden Coruscations, or Explosions ; and if confined in the Caverns of the Earth, sometimes burst and shudder those Caverns to Pieces. At which Time the hot Vapours, generated by the Explosion, and expiring through the Pores of the Earth, may raise Tempests and Hurricanes, or make the Ground sink into Chasms, or the Sea boil up in certain Places. These sulphureous Vapours at other Times ascending into the Atmosphere, may there ferment along with other Matters, take Fire, and thus Occasion Thunder, Lightning, the *Aurora Borealis*, and other fiery Meteors : At least this seems one probable

probable Cause of such Effects, and has a Foundation in Nature *.

EXPERIMENT IV.

Coruscations produced by means of Oil of Vitriol and Iron.

23. We took a cut Body, capable of holding *Artificial* two or three Quarts; and put into it three Ounces of Oil of Vitriol, and twelve of common Water; then warming the Mixture a little, we threw in, at several Times, two Ounces, or more, of clean Iron-Filings; upon which an Ebullition, and white Vapours, arose; then presenting a lighted Candle to the Mouth of the Body, the Vapour took Fire, and at the same Time afforded a bright Fulmination, or Flash like Lightning. The Candle being several Times applied, in the same Manner, afforded the like *Coruscations.* Coruscation; during which we sometimes found the Glass filled with a Flame that reached, and circulated, to the Bottom of the Liquor; and sometimes the Flame only rose into the Neck of the Glass.

24. This Experiment will not succeed, unless *Cautions.* the Oil of Vitriol be largely diluted with Water, to make the Menstruum fit for dissolving the Metal. 'Tis also requisite to heat the Liquor a little, in order to promote the Solution, that the Vapour may ascend the freer: But if the Liquor be too hot, the Vapour will rise too fast; and so, when the Candle is applied, only take fire in the Neck of the Glass, without making any remarkable Fulmination.

* See Sir Isaac Newton's *Queries*, at the End of his *Optics*; and M. Lemery's Paper upon the Subject, in the *French Memoirs*.

25. This

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Rationale. 25. This Experiment appears to have a great Affinity with the preceding, and to depend upon nearly the same Principle; the Oil of Vitriol being a very powerful Acid, corresponding to that of Brimstone; and Iron, in itself, containing something that is properly sulphureous, or inflammable. It should seem, however, that it is not the Sulphur of the Iron alone, but that some sulphureous Part of the Oil of Vitriol also contributes to the Effect; for Spirit of Nitre, or *Aqua fortis*, being used in this Case, produce no Fulmination: But the Spirits of Salt, of Sulphur, and of Allum, which are all sulphureous, have here the same Effect as Oil of Vitriol.

Discovery and Use. 26. The Experiment seems to have been accidentally discovered, by inadvertently approaching a Candle near the Mouth of the Glass, whilst Iron was dissolving in diluted Oil of Vitriol, in order to make the common Vitriol of Iron; for if what remains in the Glass after the Fulmination is over, be boiled, filtered, evaporated, and crystallized, it affords this Vitriol in great Perfection, like what we before observed of the Mixture of Iron-Filings and Sulphur *a*).

27. We would recommend it to the curious in Chemistry, to endeavour to collect, and, if possible, to condense, a Quantity of the sulphureous Vapour generated in the present Experiment: For this Vapour has not the fetid Smell of Brimstone; but is, perhaps, somewhat like that volatile, aerial Spirit, which gives Virtue to certain mineral Waters *b*).

a) See above, §. 22.

b) See *Hoffman* of Mineral Waters.

EXPERIMENT V.

Fire and Flame produced by the Mixture of two cold Liquors.

28. We took two Drams of strong and fresh Oil of Spirit of Nitre, prepared with Oil of Vitriol, *Cloves and Spirit of Nitre mixed.* and putting it into a clean and dry four Ounce Gally-Pot, we set it under a Chimney; then immediately, and at once, poured to it a Dram of the true essential Oil of *Indian* Cloves; and there was instantly produced a loud Noise, a violent Conflict and Ebullition, with a considerable Flame; which being extinguished, a resinous Substance, or actual Rosin, was found at the Bottom of the Gally-Pot.

29. To render this Experiment safe, (1) it *Cautions.* ought to be performed under a Chimney that may carry up the offensive Vapour; (2) the Oil should be poured from a Phial fixed at the end of a Stick, to prevent any of the fiery Matter from flying upon the Operator: And to render it successful, (1) the Spirit of Nitre should be strong, and fresh drawn; (2) the Oil should be genuine; (3) the Vessel wherein the Mixture is made should be perfectly clean, dry, and large enough to give the Matter room to swell; (4) the Oil should be poured in at once, to make the more expeditious Mixture.

30. This Experiment is neither confined to *Extended.* one certain Oil, nor to one certain Acid; the distilled Oil of Sassafras, Guajacum, Box, *Jamaica* Pepper, Cinnamon, or even the empyreumatic Oils of Hartshorn, Blood, &c. will serve the Purpose; or, in general, any thin, essential Oil, thickened with Balsam of Sulphur, &c. For some

some Degree of Thickness or Tenacity in the Oil seems a primary requisite, to make it explode with Spirit of Nitre; and for acid Spirits, Oil of Vitriol, and most of the other acid Spirits highly rectified, will produce Flame with the aromatic *Indian* Oils, if unadulterated.

31. The Experiment is made to give the greater Surprise when Gunpowder is fired by pouring a cold Liquor upon it; for if Gunpowder were put to the Oil, this also would be fired, upon pouring in the Spirit of Nitre. Hence it may seem strange that Camphire, which is an exceeding inflammable Substance, should not take Fire when added to the Oil, and treated as the Gunpowder. The Reason seems to be, that Camphire contains an Acid; and therefore when dissolved in the Oil, somewhat anticipates or lessens the Force of the Spirit of Nitre that is afterwards applied; so that the Shock betwixt the two is not now great enough to produce Flame: For in the Shock, or violent Conflict betwixt a strong Acid and a thick Oil, divested of Acid, the Fire and Flame in the Experiment appear to be produced.

And accounted for

Its Force in vacuo.

32. Nor is the Effect lessened when the Experiment is performed *in vacuo*; where half a Dram of Oil of Carraway-Seeds, and a Dram of Spirit of Nitre, have made a Flash like Gunpowder, and burst the exhausted Receiver, a Glass six Inches wide, and eight deep *. This is a very extraordinary Effect; as differing from most other flaming Bodies, which rather destroy than generate Air: But here must be a large Quantity of Air, or something of equal Force, generated by the exploding Mixture, in order to balance and over-power the external Pressure;

* See Sir *Isaac Newton's Queries* at the End of his *Optics*.

which

which in this Case was several hundred Weight. Hence it should seem that the Force of our explosive Mixture is much greater than that of Gunpowder; which will not explode *in vacuo*, nor, even with the Assistance of the Air, produce any thing like such an Effect. It may therefore be worth considering, whether so great a Power could not be applied to some useful Purpose. The Mixture might be made cheap, by using any of the gross and ponderous empyreumatic Oils, instead of the essential Kind.

EXPERIMENT VI.

The liquid Phosphorus of Urine.

33. We took half a Dram of Camphire, and *Solid Phosphorus* ground it in a Glass Mortar, with three Grains *phorus* of the solid *Phosphorus* of Urine; then added as much essential Oil of Cloves as served to reduce *made harmless.* the whole to a fluid Form. The Mixture thus made may be rubbed upon the Cloaths, the Hair, or the Hands, without Danger of burning *a)*.

34. Chemistry hath scarce afforded any Thing *History of* more surprizing than the common *Phosphorus*. *Phosphorus.* To see Letters traced with this Matter become *rus.* luminous in the dark, Images and the Bodies of Men to blaze with Light, and Abundance of the like Experiments performed by Means of *Phosphorus*, made many Persons curious to know how it was made *b)*. The Preparation indeed seems even to this Day kept as a gainful Secret in few Hands, and the Matter is sold at a very great Price; Whence we apprehend it would be of

a) See below under § 43. No. 11.

b) See M. Homberg's Papers on the Subject.

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singular Service to Chemistry, to render this Commodity cheaper, and discover its farther Uses.

35. With this view we shall here touch a little upon the History of this *Phosphorus*, commonly called *Kunckell's Phosphorus*, or the *Phosphorus* of Urine. It was discovered by accident: One *Brand*, an obscure Chemist of *Hamburg*, stumbled upon it as he was searching after the Philosophers Stone, which he firmly believed lay concealed in Urine. This Subject therefore he tortured a thousand Ways; and at length, after a violent Distillation, found a shining Matter, since called *Phosphorus*, in his Receiver. This Matter was shewn to Dr. *Kunckell*; but the Process was concealed from him. Soon after this *Brand* died; and *Kunckell* reflecting that *Brand* worked wholly upon Urine, he continued to work upon the same Subject himself for four years together; and at length, in the year 1679, found the Thing he sought after. Doctor *Kraft* has usually past for the Inventor of this *Phosphorus*, he being the first that carried it abroad: but he only distributed it for Dr. *Kunckell*, being at that Time unacquainted with the Preparation.

*The solid
Phospho-
rus, how
made.*

36. The successful Method of making it is this: Evaporate any Quantity of fresh Urine over a gentle Fire, to a black, and almost dry, Substance; then with two Pounds thereof thoroughly mix twice its Weight of fine Sand; put the Mixture into a strong coated Retort of Stone; and, having poured a Quart or two of clear Water into a large Receiver with a long Neck, join it to the Retort, and work in a naked Fire; let the Heat be small for the two first Hours; then increase it gradually to the utmost Violence: and thus continue for three or four Hours

Hours successively. At the Expiration of that time there will pass into the Receiver a little Phlegm and volatile Salt, much black fetid Oil, and lastly the Matter of the *Phosphorus* in Form of white Clouds, which will either stick to the Sides of the Receiver like a fine yellow Skin, or fall to the Bottom in Form of a small Sand. Now let the Fire go out; but take not away the Receiver before it is cold, for fear of setting the *Phosphorus* on fire, by admitting the Air. To reduce these small Grains into one Piece, put them into a little Tin Ingot-Mould, along with some Water; heat the Ingot, to make the Grains melt together; then add cold Water, till the Matter is congealed into one solid Stick, like Bees-Wax; which being cut into little Pieces fit to enter the Mouth of a Phial, may be preserved by Water, and by keeping the Glass close stopped. If the Glass be not kept stopped, the *Phosphorus* will turn black on its Surface, and at length be spoiled.

37. The Cautions required to make the Process succeed are, (1) to evaporate the Urine, while it is recent; (2) to prevent its boiling over, and so losing the most unctuous Part; (3) to let the Matter afterwards Ferment in the cold: (4) to mix the black Matter with Sand, to prevent its melting and running together; (5) to use a Stone Retort, those of Earth being too porous, and suffering the *Phosphorus* to transude sooner than pass into the Receiver; (6) to have the Receiver very large, and with a very long neck, to prevent its breaking and overheating, which would either evaporate the white Vapour wherein the *Phosphorus* consists, or else prevent its coagulating; (7) to put Water into the Receiver, for keeping it cool, and quenching the *Phosphorus*, as it falls to the Bottom; (8) to

(8) to make the Fire small at first, that the Retort may be preserved, and the black Matter gradually dried, which would otherwise swell, and come over in a black Froth; *Lastly*, it is found necessary, that the Urine for the Operation be of such as use Malt-Liquors, rather than Wine. All these Circumstances being required for obtaining the *Phosphorus* to advantage, no wonder if so many have miscarried in their Attempts to make it.

*The Process
shortened.*

38. This Operation may be greatly shortened, by freezing and concentrating fresh Urine, afterwards evaporating it with care, and then digesting it *per se* in the Manner above mentioned. When thoroughly digested, commit the Matter, in a large Quantity, to an Iron Pot, with an earthen Head, as the Chemists usually do for making Spirits of Hartshorn, or the Spirit and Salt of Urine. When all the Salt and Oil are thus obtained, let the *Caput mortuum* be taken out, and mixed with twice its own Weight of Alum. This Matter may now be put into a well coated Long-Neck, and worked with care in a Reverberatory Furnace, into very large Receivers, filled with Water, and connected to the Long-Necks by Adapters; the lower Ends whereof should enter the Water, as in distilling Quicksilver, and the Operation be continued for eight or ten Hours. And this we apprehend to be the best Way hitherto known of procuring *Phosphorus* to Advantage. Dr. Wall informs us that Mr. Boyle, concerned to find how small a Proportion of *Phosphorus* was afforded by Urine, desired him to look out for another Subject that might afford it in greater Plenty. The Doctor afterwards causing a Piece of dry Matter to be dug up in the Fields where Night-men emptied their Carts, he observed a great Number

ber of small Particles of *Phosphorus* therein. This Matter the Doctor immediately carried to Mr. Boyle, who set Bilgar the Chemist to work upon it: But he could obtain very little *Phosphorus* from it, till another Material was added thereto in Distillation; and then he procured *Phosphorus* in such plenty that, selling large Quantities at six Guineas the Ounce, he soon became rich and left *England* *. The Matter which thus fixes and increases the *Phosphorus*, we apprehend to be Alum; which is itself not only in some Measure prepared from Urine, but appears to afford the same Kind of Acid that *Phosphorus* yields by burning. For upon its Analysis, *Phosphorus* appears to be a Composition of a strong Acid and an inflammable Matter united, exactly in the Manner of common Brimstone; whence it may not improperly be called an *animal Sulphur*: And accordingly, like common Brimstone, it will burn under a Glass Bell, and afford Flowers which, by attracting the moisture of the Air, become an acid Liquor like *Oleum Sulphuris per Campanam*.

39. And in this Manner it has been used, so as *Farther* to produce extraordinary Changes upon Metals, *Uses*. especially in the philosophical View; the Acid itself, even without Heat, proving a Menstruum to perhaps all the Metals. But when this Acid is driven into the Pores of the Metal, by the Action of the Flame in burning the *Phosphorus*, it seems productive of much greater Effects; as is known to those acquainted with the sublimer Metallurgy. And it is principally with a View of promoting this Kind of Experiments, that we have bestowed so much of our Lecture upon facilitating the Method, and easing the Expence,

* See the *Philosophical Transactions*.

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of preparing this *Phosphorus*; which of all the Kinds hitherto discovered seems the most useful.

*Other
kinds of
Phosphori.*

40. This *Phosphorus* has been several Ways disguised, so as to make it appear under various Forms; sometimes as a Solid, sometimes as a Liquid, sometimes as an Ointment, sometimes as a running Mercury. There are also others of different Kinds; of which we shall only mention two, both discovered by M. *Homberg*. The

*The black
Phosphorus.*

first is that usually called the *Black Phosphorus*, now commonly prepared with Alum and Wheat Flower, by taking four or five Parts of Alum to one of Wheat Flower, and calcining them together to a brown or blackish Mass; which being powdered, is put into a Phial, loosely stopped with Paper, and set in a Sand-Heat, so as to continue glowing hot for some time; then the whole is removed from the Fire, suffered to cool gradually, and at last the Bottle is stopped close. A little of this Powder being poured out of the Bottle, and exposed to the open Air, immediately takes Fire, and appears like a glowing Coal. But the Powder must be fresh made, to have a strong Effect; for the Sun's Rays, or the Moisture of the Air, being gradually admitted to it, destroy its Virtue: whence it ought to be kept in a dark and dry Place. 'Tis remarkable of this *Phosphorus*, that it may be made from almost any animal or vegetable Substance, instead of Wheat Flower; but that no Salt whatever can be substituted instead of Alum.

*The Phos-
phorus of
Sal-Am-
moniac and
Lime.*

41. M. *Homberg*'s other *Phosphorus* is made of one Part Sal-Ammoniac, and two Parts Lime slaked in the Air; these being mixed well together, a Crucible is to be filled with them, and set in a small Fire of Fusion; where, as soon as the Crucible becomes red hot, the Mixture will melt, and should be stirred with an Iron Rod,

to

to prevent its running over. When the Matter is entirely fused, it may be poured into a Brass Mortar; and when cold it will appear of a grey Colour, and almost as if it were vitrified. If now it be struck with any hard Body, it appears as on Fire in the whole Extent of the Stroke; but the Matter being brittle, it may be proper for the Experiment's sake, to dip little Bars of Iron, or Copper, into the melted Matter in the Crucible; for thus they will be enamelled, as it were, with the Matter; and these Bars may be struck upon, so as commodiously to repeat the Experiment several Times before the Matter falls off. The Bars are to be kept in a dry Place, to prevent the *Phosphorus* upon them from running by the Moisture of the Air.

42. Both these *Phosphori*, were discovered by Accident: The first was obtained by searching for a limpid Oil, from the common stercoraceous Matter, that should fix Quicksilver; and the second, by endeavouring to calcine Sal-Ammoniac with Lime, so as to render it fusible like Wax; which end was obtained, but not the other.

*Discovery
of Phos-
phori ac-
cidental.*

43. There have been no very considerable Uses of these two *Phosphori* hitherto discovered; but the *Phosphorus* of Urine has been employed for making many curious Experiments; a few whereof we shall here exhibit.

(1) The Light of this *Phosphorus* appears greater *in vacuo* than in the open Air.

*Experi-
ments*

(2) In hot weather it is observed to dart Flashes of Light through the Water wherein it is contained, so as exactly to resemble Lightning; which thus darts unextinguished through watery Clouds and Vapours.

*with the
Phosphorus
of Urine.*

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(3) These Flashes of Light are not apt to kindle or burn any combustible Matter, in which they resemble the harmless Kind of Lightning; but in a condensed State this *Phosphorus* burns very furiously, and with a most penetrating Fire, so as to melt and dissolve Metals: In which respect it again resembles the more destructive Kinds of Lightning, which are found to have the same Effects.

(4) If a little Piece of this *Phosphorus* be viewed through a Microscope, the internal Parts appear in a constant Ebullition.

(5) A little Piece of it being put into a Silver Spoon, and held over the Fire, it bursts out into a shining Flame, leaving a red spot in the Spoon of a corrosive, acid taste; which being diluted with Water, the Mixture makes a conflict with Oil of Tartar *per deliquium*.

(6) If a little of it be ground in a Glass Mortar, with twenty times its own Weight of Nitre, it does not take Flame, but only disperse a shining Property through the Body of the Nitre; but if ground in the same Manner with Iron-Filings, reduced to Powder, a bright Flame immediately ensues.

(7) Though this *Phosphorus* appears to be a Kind of Sulphur; yet it does not dissolve in high rectified Spirit of Wine, but communicates some sulphureous Parts thereto: For if this Spirit be poured to Water in the dark, it yields a faint Degree of Light.

(8) The Nature of this *Phosphorus* is considerably changed, by being long digested with Alcohol: For thus it becomes a Kind of white transparent Oil, that does not coagulate without an extreme Degree of cold, nor afford any Manner of Light; and when fresh Spirit of Wine

Wine is poured thereon, it does not like other Oils, mix therewith, nor dissolve therein.

(9) If this *Phosphorus* be separated from the Spirit of Wine wherewith it was digested, and be afterwards well washed in common Water, it, by Degrees, recovers its former Consistence, and coagulates into a transparent Matter, whiter than before; but neither affords so much Light, nor recovers its primitive shining Virtue, nor its yellow Colour.

(10) The Spirit of Wine so separated becomes yellowish, and smells strong of the *Phosphorus*; though it shines not, except when poured upon Water.

(11) This *Phosphorus* being mixed with a large Quantity of Pomatum, makes, as well as with Camphire and the Oil of Cloves, a shining Unguent, that may be rubbed on the Hands and Face, without Danger of burning, so as to render them luminous in the Dark.

(12) If a Piece of Paper, or Linen, be dipt at one End in Spirit of Wine, and a Bit of *Phosphorus* be crushed on the other End that remains dry, the Spirit will be fired by the *Phosphorus*, without immediate Contact: But the same Thing will not happen, if the Paper were dipt in Oil of Turpentine, nor if a Bit of *Phosphorus* were rubbed upon the End dipt in the Spirit of Wine; only when the Spirit is entirely evaporated the *Phosphorus* will burn, though with Difficulty, and slowly.

44. There are many of these odd Kind of Experiments that might be made with *Phosphorus*; which is a Substance that seems, in Chemistry, to be much such a Thing as the Loadstone in Natural Philosophy; and its effects are almost as odd and difficult to explain, for want of knowing the latent Properties of Bodies.

AXIOMS and CANONS.

1. We learn from the preceding Experiments, That Gunpowder, and the Arts thereon depending, are capable of farther Improvement; and that more forcible and destructive Inventions, than those at present in Use, are discoverable, if required *a*).

2. That, in particular, great Use may be made of compressed Air in this Way, the Mixture of Iron-Filings and Brimstone, in large quantities; the *Pulvis* and *Aurum fulminans*; Salt of Tartar; the Mixture of certain cheap Oils and acid Spirits, for producing extremely powerful and destructive Effects *b*).

3. That many natural Phænomena, such as Earthquakes, Thunder, Lightning, Vulcanos, the *Aurora Borealis*, Hot Baths, &c. are imitable and explicable by chemical Experiments, particular Mixtures, and explosive Powers *c*).

4. That Fire and Flame are producible by the simple Mixture of appropriated Bodies, if made with sufficient Violence: or that Oils freed of their acid Part, and suddenly joined with strong acid Spirits, are instantaneously productive of Fire and Flame *d*).

5. That by this Action, or the intimate and strong Union of acid Spirits with Oils, Rosins are producible *d*).

6. That very violent Explosions may be made *in vacuo*, as well as in the open Air *d*).

7. That the *Phosphorus* of Urine is applicable to many extraordinary Purposes; particularly to the introducing of uncommon Changes in metal-line Bodies *e*).

a) See Exp. I. II. and V. *b*) Exp. I. II. III. V. *c*) Exp. III. IV. V. VI. *d*) Exp. V. *e*) Exp. VI.

8. That

8. That as most Discoveries of chemical Explosions and *Phosphori* were accidental, greater Things may be expected from a sagacious Experience, conducted by Reason, and by a farther Discovery of Causes and Axioms *a*).

9. That the *Phosphorus* of Urine may be made in large Quantities, and with small Expence; so as to afford desirable Opportunities for the farther Improvement of Chemistry and Metallurgy *b*).

10. That there may be many latent Properties in Bodies, remaining unknown to us, for Want of making the proper Experiments; which alone can discover, and bring those Properties to light *a*).

a) See Exp. I. II. III IV. V. VI.

b) Exp. VI.

LECTURE XX.

CONTAINING

Ways of applying Chemistry to the farther Service and Improvement of Natural Philosophy, Arts, Trades, and Business.

I.

Design.

1. OUR present Lecture is intended to shew some particular Ways of extending and applying Chemistry to the farther Improvement of Natural Philosophy, Arts, Trades, and Manufactures. For though this be the general Design of our whole Course, yet we judge it proper to bestow our last Lecture expressly upon the Subject. We shall therefore (1) divide Chemistry into its several Branches, and shew how each of them may be farther improved; (2) exhibit a set of Experiments tending to that End; and (3) offer a few Rules for its farther Application and Enlargement.

Chemistry divided,

2. *Chemistry*, in general, may be usefully divided into Philosophical, Technical, Commercial, and Oeconomical Chemistry.

Into Philosophical,

3. By *Philosophical Chemistry* we understand Chemistry practised in Miniature, after the Manner of our present Course; so as to find out the Causes of physical Effects, and to make new Discoveries in Nature *.

* See below § 7.

Of Enlarging Chemistry, &c.

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4. By *Technical Chemistry* we understand the *Technical*, Application of Philosophical Chemistry to the immediate Service of some Art; so as to invent, form, assist, promote, or perfect it in the large Way of Business.

5 By *Commercial Chemistry* we mean the Appli- *Commer-* cation both of Philosophical and Technical Che- *cial*, mistry to the establishing, supporting, and improv- ing any Branch of Trade or Commerce.

6. And by *Oeconomical Chemistry* we mean the *And Oeco-* Application of Philosophical, Technical, and Com- *nomical*. mercial Chemistry to the Service and Accommodation of a Family.

7. Philosophical Chemistry consists of three *Philosophi-* Parts; viz. *Invention, Rationale, and Experiment:* *cal Che-* Whence we may define it a particular Exer- *mistry;* cise of the rational and inventive Faculties of *its Parts:* the Mind, leading to Experiments, and thence to the Discovery of Causes; so as to form Axioms, that shall rationally Account for Phænomena, and discover Rules of Practice for producing useful Effects. And thus Philosophical Chemistry is not only a Key to all the other Parts, but of itself discovers the Causes of many natural Phænomena; as particularly Earthquakes, Vulcanos, Vegetation, the growth of Minerals &c.

8. This Branch of Chemistry also explains the *Its Office*, general Forms and Qualities of Bodies, whereon their Properties and Effects depend; as Volatility and Fixedness, Fluidity and Firmness, Colours, Tastes, Odours, Effervescences, Fermentation, Solution, Precipitation, Congelation, Extraction, and the like.

9. To this Part of Chemistry it likewise belongs to bring new Inventions to the Test, so as to discover their Validity or Insufficiency. Thus when any Hint is started for a new Trade, or Method

Method invented for the Improvement of an old one, before any Attempt is made to apply it in the larger Way, the proper Assay or Experiment must first be performed in Miniature; where if it prove successful, this may rationally encourage the erecting of such a Discovery into an Art, or its Application to the Improvement of Business.

Illustrated. 10. To have an Example of this whole Procedure, we need but reflect upon the general Office of the Assay-Master; who before-hand discovers, in Miniature, the Quantity of Metal contained in any Ore assigned; thereby giving a Direction to the Operator at the larger Furnace. And thus Philosophical Chemistry plays directly into the Hands of the Technical, Commercial, and Oeconomical Species.

Its Improvement, by a portable Laboratory. 11. But before it can do this to the best Advantage, there are several Deficiencies therein that require to be supplied: And first, the Labour, Time, and Expence necessary to procure the proper Furnaces, Vessels, Utensils, and Subjects, for the ready and commodious Exercise of this Art, have been a great Hindrance to its Advancement. Upon which Consideration we have endeavoured to collect together a commodious *Philosophical Laboratory* in a portable Form attended with as many Conveniencies as the Nature of the Thing will allow *a*).

By practising it, without Fire or Furnace. 12. In our Definition of Chemistry *b*), we endeavoured to avoid the common Error of confining this Art to the sole Use and Application of Fire. We hope to have shewn *c*) that it has a Right to employ the other Elements, Air, Water, and Earth; to which we may add Cold,

a) See the Essay for introducing a Portable Laboratory.

b) *Lect. I. in init.*

c) *Lect. I. II, III, IV.*

and various Kinds of Motion. And if it be remembered, that Chemistry is the Art of analysing and compounding Bodies by Means of all the Instruments we can procure; an Attempt to introduce Ways of working in the Art, without Fire or Furnace, will not appear surprizing.

13. Nay, if a due Estimate were made, and the full Scope and Extent of Chemistry considered; a large and curious Part of it would appear to depend more upon other Things, than upon the direct Use of Fire: Thus for Example, the whole of Fermentation and Putrefaction, two Extensive Operations in Nature and Art, are performable without the Use of either Fire or Furnace. Farther, the Action or instrumental Efficacy of Air, Water, and Earth might, with regard to chemical Operations, be opposed to the Action of Fire; which has still a more direct Antagonist, or rather Correlative, viz. Cold; whose Efficacy in Chemistry is extremely great, and separates the more useless and aqueous Parts of Bodies from those that are more spirituous and essential; as we see in the Concentration of Wines, Vinegars, and other spirituous and saline Liquors by Frost *.

14. There is farther wanting to the Improvement of *Philosophical Chemistry*, a Collection of all that is hitherto known and practised in the Art, to shew the present State and Condition thereof. And this, perhaps, would make no very large Volume; for the original Experimental Writers are very few, in Comparison of the Collectors and Transcribers: But the more useful Part of such a Work is not to be found in Books; and can be had only from observing, collecting,

Particularly by means of Cold.

Chemistry improveable by collecting the Experiments and Practices of Artists.

* See the last of three Essays in Artificial Philosophy, or Universal Chemistry, *Ann.* 1731.

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and digesting the daily Practices of mechanical Operators ; such as Refiners, Assay-Masters, Smelters, Dyers, Sugar-Bakers, Soap-boylers, &c. And till the Secrets and Mysteries of these Arts are known to the chemical Philosopher, he will want many things that are necessarily required to the Improvement of Philosophical Chemistry.

*A List of
Desidera-
ta.*

15. The last particular we shall at present intimate, as wanting for the Exercise and Improvement of Philosophical Chemistry, is a List of the Chemical *Desiderata* in all Arts and Trades, in order to procure the readiest Ways of supplying them : For such a List would contain so many Problems for the Philosophical Chemist to solve.

*Technical
Chemistry
divided.*

16. We now proceed to *Technical Chemistry* ; which, for the Sake of Use and Commodiousness, we divide into four Parts : as it relates to Subjects of the animal, vegetable, and mineral Kingdoms ; or to several of them at once. Thus under animal Arts comes the Art of preparing Size and Glue, Tanning, Ivory-Staining, the Dying in Wool, Silk, &c. Under vegetable Arts comes the Art of Timber, or the Ways of preserving it sound against the Injuries of the Weather, the Sea, &c. the Art of making Rosin, Pitch, Oil of Turpentine, Charcoal, Pot-Ash, &c. the Art of Brewing, and Fermenting for Wines, Vinegars, &c. the Art of Sugar-making, and Refining ; the Art of Soap-making, &c. Under mineral Arts come the Arts of Salt, Copperas, Vitriol, Borax, Pottery, Metals, Foundry, Smithery, &c. And lastly, under mixed Arts comes the Art of Paper, the Art of Ink, the Art of Japanning, the Art of Glass, the Art of Pigments, the Art of Pharmacy, the Art of Fire-Works, &c. all which are proper

proper chemical Arts, that fall under Technical Chemistry.

17. It were easy to give a Catalogue of a large Number of new, and probably advantageous, Arts or Trades, that might be set up in *England*. Thus, for instance, we would recommend the Introduction of *English* Arracks and Brandy; which might be plentifully afforded by the Tappings of our Trees, and all Kinds of Summer-Fruits: Nor need Wines themselves, even from the Grape, be here excepted; especially as we have an excellent Method of improving all poor and thin Wines, by adding fine flavourless Sugar in the Fermentation *.

18. We have endeavoured to shew, in the preceding Lectures, that many of our Trades are improveable; particularly Brewing, Distilling, Soap-boiling, Pharmacy, Metallurgy, &c. And for new Trades, that the refining and making of various Commodities may be as advantageously practised in *England* as elsewhere: And among these may be reckoned the refining of Borax, Camphire, Tartar, Manna, &c. the making of Salt-Petre, the obtaining of Sulphur, the making of blue Vitriol, Porcellane, artificial Gems, and numerous other Commodities of Price and Use.

19. The great thing wanting to the Advancement of Arts, and the Perfection of this whole Affair, seems to be the joint Concurrence of certain Persons, who should contribute to the carrying it on. The Compass of Knowledge allotted to a single Man or two, bears no Proportion to that required for the due conducting of this Work: Nor, perhaps, is the Knowledge in being, of the Kind here principally required.

* See *Lect.* XI.

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Arts and Sciences must receive their Improvements chiefly from *Physical Knowledge*; that is, a Knowledge drawn from the Nature of Things, which is to be acquired only by conversing with natural Bodies, and observing their Properties, by putting Bodies together, and separating them again. And this general Process is to be conducted in the way of a *sagacious Experience*; which is a Matter of Judgment, not casual or accidental, but formed upon some certain Principles and Analogy of Knowledge. Thus we see, in ordinary Life, and the Practice of Trades, that Men educated to them have an acquired Sagacity, or Habit of judging each in his own way; which Sagacity is rarely to be found in Men differently educated. The Qualifications therefore required for our present purpose may be termed, *Physical or Chemical Habits of judging about Things relating to Arts and Trades*, acquired by some competent Experience, or by being for some Time versed in this Way.

20. If Choice were made of a Set of Men so qualified, and Rules given them to pursue, with due Care to register all their Experiments, and form them into *Tables*, from whence some should derive Canons and Axioms, others deduce the more useful Things for the Service of Arts and Trades, &c. So as to make an uniform and steady Business of the whole; there is good Reason to expect that, in the compass of a few Years, considerable Improvements might be made in the present set of Arts and Sciences.

Commercial Chemistry divided.

21. *Commercial Chemistry* consists of three parts, viz. (1) The Exercise of all the Chemical Arts, in a large Manner; so as to supply more than the Demands of a single Country, and afford a Surplus of Commodities for Exportation and foreign Consumption; (2) The various Ways of con-

condensing, curing, preparing, securing, and fitting natural and artificial Commodities for Carriage and Transportation; And (3) the Ways of supplying the chemical Necessaries to Voyagers and Travellers, for founding, supporting, and improving Trade, Traffic, and Commerce, in different Countries.

22. And thus a Knowledge of *Commercial Chemistry* will easily direct us in *England*, to the *How to be improved.* Arts that may be extended and improved, so as to undersell some other Nations at the foreign Markets; provided the Duties and Drawbacks are in our Favour: For example; We conceive, that Malt-Spirit may be produced in *England* cheaper and better than in *Holland*; that Wines, Vinegars, Brandies, and Arracks, may be made, either here, or in our Plantations, as good as, and perhaps cheaper than, in their present places of growth and Importation; that White Lead, Verdigrease, Sal-Amoniac, Pot-Ash, Hard Soap, &c. may be prepared as cheap and good in *England* as in any other Part of *Europe*.

23. We are likewise instructed by *Commercial Chemistry*, to reduce Goods to their least Volume or Bulk for Exportation; and again to secure them from the Injuries of the Sea, the Weather, and other Accidents. Thus Metals come to be exported instead of their Ores, Sugars instead of the Juice or Rob of the Sugar-Cane, Salt instead of Sea-Water, Raisins instead of Grapes, high Spirits instead of low Wines, Pot-Ash instead of refuse Wood, &c. And thus it is that, by means of Technical and Commercial Chemistry together, different Countries are supplied with Lead, Tin, Iron, Silver, Oil, Tallow, tanned Hydes, Pitch, Rosin, Brimstone, Wax, Wines, Brandies, Salt, Sugars, Treacle, Paper, &c. whereby all
Trade,

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Trade, Traffic, and Commerce, is supported. And to discover this Kind of Contrivance, or Reduction, is the Office of Commercial Chemistry. Thus, instead of importing many Tuns of a foreign dying Wood, we are taught to extract its tinging Parts, and bring them away in the Quantity of a few Pounds. And to do this more generally, as it may be done, would tend to perfect the Trade of the Dry-Salter, and lessen the Expence of the Dyer.

24. Another Advantage of *Commercial Chemistry* is, that it affords the Necessaries for long trading Voyages. Thus, in particular, it directs us to a *Chemical Chest*, and a *Portable Furnace*, with its Apparatus of Flux-Powders, for assaying Ores; a Screw-Press for Oils, and a Still for examining fermented vegetable Juices. It also directs us to the certain Rules of discovering the Sophistications practised in Wines, Brandies, Vinegars, Arracks, Gold-Sand, Gold in Bars or Ingots, counterfeit Gems, &c. and to the ways of assaying Pot-Ash, Tincal, Amber-grease, Musk, and all other Drugs. So that to improve this Part of Chemistry, little more seems required than the bringing it into more general Use; which might be done to great Advantage, if Philosophical and Technical Chemistry were first improved to any considerable Degree.

Oeconomical Chemistry divided.

25. We now come to our last Division of Chemistry, viz. the *Oeconomical Branch*; which is of great Utility and Extent, so as to be capable of improving all the rest. This Branch we choose to divide with regard to the several Offices of a House, in which, as in so many different Laboratories, it may be commodiously practised: For Instance, in the Brewhouse, the Store-Room, the Kitchen, the Dairy, the Laundry, and the Cellar. Thus, by Means of
Oecono-

Oeconomical Chemistry, we are instructed in the best Ways of brewing with Malt, Treacle, Hony, Sugar, or other vegetable Juices; the best Ways of raising and preserving Yeast, or Wine Lees, for baking or brewing; and of imitating the natural Wines of foreign Growth. This Art directs us how to procure the simple and compound Waters of Vegetables, in their greatest Perfection; and to make a Set of Brandy or Cordial Waters, even from the gross Lees, Sediments, or Bottoms of our Wine or Ale Casks. Hence also we learn the Methods of preserving Fruits in Sugar, and several vegetable Productions in the Way of Pickle, &c. The Art of Cookery also is by this Means improveable: So are all the Dairy Productions, and the Business of the Laundry; as by rendering hard Waters soft, &c. But to shew this fully, and to improve the Design, would require a particular Treatise, under the several Heads of the *Brewhouse*, the *Store-Room*, the *Kitchen*, the *Dairy*, the *Laundry*, and the *Cellar* *.

II.

26. We now proceed to our Experiments; *Purpose of the Experiments.* the *first* whereof will shew that Sal-Ammoniac may probably be made to as great Advantage in *England* as in the *Levant*; the *second* will shew the Method of making a Varnish of Amber, with a View to improve the Arts of Japanning, Embalming, &c. the *third* will shew how to make a very hard Glass, for improving the Art of Glass, Enamelling, and the Business of artificial Gems; the *fourth* will shew how to prepare a Foil for foliating figured Glasses, and

* See the first of the three Essays in *Artificial Philosophy*, or *Universal Chemistry*, published in 1731.

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turning them into Speculums; the *fifth* will shew a Way of making a curious and useful Glue; and the *sixth* and last will shew a Method of giving Copper a Gold Colour, and a greater Degree of Ductility, by Way of directing an Enquiry after Methods of introducing other useful Changes into Metals.

EXPERIMENT I.

That Sal-Ammoniac may be advantageously made in England.

Sal Ammoniac prepared. 27. We took four Ounces of the common volatile Salt of Ox-Bone, and saturating it with strong Spirit of Sea-Salt, evaporated the superfluous Moisture; upon which we found a Cake of true Sal-Ammoniac left behind.

Use of the Experiment. 28. This Experiment regards both Philosophical and Technical Chemistry; as not only shewing that Odours may depend upon the Mechanical Structure or Texture of the Parts of Bodies; but also leading to a cheap Way of obtaining Sal-Ammoniac in other Countries, as well as in the *Levant*.

In Philosophical Chemistry, or the Doctrine of Odours. 29. The volatile Salt here employed has a very quick and -pungent Odour; so likewise, though in a less Degree, has the Spirit of Salt: but these two, upon mixing, destroy each other's Odour, so as to leave the Cake of Sal-Ammoniac scentless. The Reason is, that these two odorous Liquors lose of their Volatility by Mixture; so that their fine Parts can no longer fly off briskly, and strike the Nerves of the Nose, on which all smelling depends. But if a little of the Sal-Ammoniac be ground in a Mortar, along with another scentless, but more fixed, Body, viz. an equal Quantity of Salt of Tartar; this Salt

Salt of Tartar laying hold of the Acid of the Sea-Salt, leaves the volatile Salt at Liberty to ascend and strike the Noftrils as briskly as before: Whence we see that Odours may be mechanically produced and destroyed. The same is confirmed by many other Instances of Philosophical Chemistry, and holds equally of Tastes.

30. Hence we may derive some Rules for improving the Odours of certain Perfumes, or for recovering them when impaired, or almost destroyed. Thus it is known to Perfumers, that Sugar being ground with Musk or Ambergrease, opens the Body thereof, and makes these Substances go farther in the perfuming of Waters, Powders, or the like: And this the Sugar does chiefly, by attenuating, resolving, and subtilizing the viscous Parts of those Sweets, so that they now move more freely, and strike the Noftrils more briskly, than before. And when these, or other Perfumes, have almost lost their natural Odour, it may in good Measure be recovered by the prudent Addition of a little volatile, animal Salt; as that of Hartshorn. And hence we see the physical Reason why decayed Perfumes are sometimes suspended in a Jakes, to recover their lost Odour; for all such Places abound with volatile Salts, continually arising from the Urine, and other animal and vegetable Matters, which are there in a State of Putrefaction.

31. Sal-Ammoniac is also obtainable in *England*, by subliming a Mixture of Wood-Soot, Urine, and Sea-Salt; but it seems easier and perhaps it might prove cheaper, to prepare it in the Way of the present Experiment. The volatile Salt for the Purpose will be abundantly supplied by the Pith of Horns, Blood, the Refuse

*Rules for
improving
Perfumes.*

*Sal-Am-
moniac
obtain-
able.*

of a Slaughter-house, putrified Vegetables, &c. and the Spirit of Salt may be made at an easy Rate, in a proper Furnace.

The Experiment extended.

32. But the present Experiment might prove still more serviceable, by leading to a Way of procuring other saline Bodies besides Sal-Ammoniac: For it should seem that several Salts may be artificially composed by the Union of their constituent Parts; as we here see in Sal-Ammoniac. For Example; the Making of blue Vitriol may be attempted, by boiling Copper, instead of Iron, in the raw Liquor of the Pyrites, from which the common green Vitriol is made. And if this Hint were duly pursued, perhaps it might lead to the Discovery of several new Arts and Trades.

EXPERIMENT II.

An Amber Varnish.

Amber dissolved.

33. We took four Ounces of Amber, and putting it into a Crucible, just melted it with a small Degree of Heat; then poured the fluid Mass upon the Iron Plate. When the melted Matter grew cold, we reduced it to Powder; and adding thereto two Ounces of drying Oil, (that is, Linseed Oil prepared, or thickened, by boiling it with a little Litharge) and one Pint of Oil of Turpentine, we dissolved the whole together into a Varnish.

Use of the Experiment.

34. This Method of making the Amber Varnish is kept as a Secret in few Hands; but deserves to be made publick, as a leading Experiment, to direct the Means of perfecting the Arts of Varnishing and Japanning, or the Ways of dissolving Amber; whereon the Perfection of various Arts may depend. Thus, in particular, the

the Art of Embalming would be highly improved, if we could preserve the human Corps in a transparent Case of Amber; as we see the Bodies of Flies, Spiders, Grasshoppers, &c. are, to great Perfection.

35. An useful Substitute, or Approximation, *Approximation.* in this Way, has been tried, by boiling fine Rosin to Colophony, or a transparent and hard, though brittle, Substance. This being dissolved by Heat, and the Bodies of some small Animals dipped therein several times successively, they have been thus coated over with Colophony; which in some Degree resembles Amber, but requires to be carefully kept from Dust, in order to preserve its Transparency.

36. But if Amber could be dissolved without *Uses of dissolving* impairing its Transparency; or if one large Mass *Amber.* could be made of it, by uniting a Number of small ones, it would thus not only tend to perfect the Art of Embalming, but likewise come to be used, on many Occasions, instead of Wood, Marble, Glass, Silver, Gold, and other Metals: for then various Kinds of Vessels and Utensils might be commodiously made thereof.

37. To forward the Discovery, our present *How to attempt its Solution.* Experiment shews, that Amber contains a certain slimy, aqueous, or mucilaginous Part, which in the ordinary Way requires to be evaporated by a scorching Heat, before the Amber will readily dissolve in Oil; with which however it afterwards unites into a Substance of a Nature compounded of that of an Oil, a Gum, and a Rosin. Nor would the thin ethereal Oil of Turpentine dissolve it, unless first thickened, and fitted for this Purpose, by Means of the drying Oil. Hence, as it seems plainly intimated that Amber is not only resinous, but also mucilaginous, whoever would attempt to melt small Pieces

of Amber into large ones, would do well to consider the Subject as a mucilaginous Resin, and consequently (1) fitted to dissolve, in a thick Oil, after a previous Evaporation of its aqueous Parts, or the Destruction of its more mucilaginous Nature; (2) that it may possibly be dissolved, by boiling in a Lixivium of Salt of Tartar, and Quicklime; or if any could be found, as there may, still sharper, and more alkaline; and (3) that the Digestor seems well adapted to dissolve this mucilaginous and resinous Substance, by Means of an expressed Oil added to the Amber, finely powdered and kept from scorching by the Interposition of Water. And here we recommend a long and moderate Digestion, rather than a violent Heat. Thus, therefore, our present Experiment points out to us three Methods for dissolving Amber, which either do not considerably destroy its Texture, or at worst leave it in a State reducible, by an easy Operation, to a Kind of Amber again.

EXPERIMENT III.

A harder Glass than the common.

*Borax
Glass.*

38. We took four Ounces of Borax, and an Ounce of fine white Sand, reduced to Powder, and melted them together in a large close Crucible, set in a Wind Furnace, keeping a strong Fire for half an Hour; then taking out the Crucible, and breaking it when cold, we found at the Bottom a pure hard Glass, capable of cutting common Glass almost as well as a Diamond.

*Use of the
Experiment.*

39. We have here an Experiment, which, being duly varied, may lead to some considerable Improvements in the Arts of Glass, Enamels, and artificial Gems: It shews us an expeditious Method

Method of making Glass, without the Use of a fixed Salt; which has generally been thought an essential Ingredient in Glass, and which is the Ingredient that gives the common Glass its Softness. But Borax is a neutral Salt, which, being urged by the Fire, does not turn any Way alkaline; but, of itself, without Addition, presently runs into Glass. And whether other Ingredients might not here be advantageously substituted for soft Sand, particularly calcined Flints, powdered Crystal, &c. we recommend to farther Experience; so as to attempt making a Glass that shall, in some Degree, approach the Hardness of a Diamond.

40. If a pure transparent Glass, of this Degree of Hardness, can be tinged in the ordinary Manner, by Means of the prepared metalline Calces, it should seem that the Art of making counterfeit Gems would then have gained its Perfection; for the Colours thus introduced are in no respect inferior, but perhaps superior, to the natural Colours of the Sapphire, Emerald, Ruby, &c. So that nothing more seems wanting to perfect this Art, than the Discovery of a dense, hard, crystalline Glass, that shall polish like Crystal, and not scratch in the Wear.

41. In order to give our Glass the desired Degree of Hardness, it may be proper to continue it long in the Fire; which is constantly found to add Strength and Hardness to Glass: Insomuch that common Glass, by being constantly kept in a strong Fusion for a Month or six Weeks, has become of a stony Hardness; a large Part of the fixed Salt thus going off in the Fire; and consequently leaving the Glass less charged with Salt, or nearer approaching to the native Hardness of the Flint or Sand employed in the Preparation.

The Experiment extended.

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42. If the Use of Borax should, in this Manner, be found to have a considerable Effect, it will be proper to enquire farther into its natural and chemical History, which seems at present to be little regarded. Perhaps it may not be impossible to find this useful Substance in some Parts of *Europe*, or to imitate it by Art, and to discover better Ways of refining it than those now usually practised.

43. The Facility wherewith this Salt runs into Glass, or the small Degree of Heat, and the short Time required for that Purpose, if well attended to, may be capable of enriching Chemistry, and more particularly the History of Glass; at least we have good Reason to believe that the present Experiment is capable of being largely diversified, and improved to the Service of several Arts.

EXPERIMENT IV.

A Foil for turning spherical or other figured Glasses into Speculums.

*The Silvering
Amalgam.*

44. We took half an Ounce of clean Lead, and melted it with an equal Weight of pure Tin; then immediately added half an Ounce of Bismuth, and carefully skimmed off the Dross: Now removing the Ladle from the Fire, we added, before the Mixture grew cold, five Ounces of pure Quicksilver, and stirred the whole well together; then put the fluid Amalgam into a clean Glass.

*How to be
applied.*

45. When this Amalgam is used for Foiling, or Silvering, let it first be strained through a linen Rag; then gently pour some Ounces thereof into the Glass intended to be foiled. The Mixture should be poured into the Glass by Means of a paper Funnel, reaching almost to the

the Bottom, to prevent its flying to the Sides; then dexterously inclining the Glass every Way, endeavour thus to fasten the Foil. When this is once done, let the Glass rest for some Hours; then repeat the Operation, till at length the fluid Mass is evenly spread and fixed over the whole internal Surface; as it may be known to be by viewing the Glass against the Light. The superfluous Amalgam being now poured out, the Outside of the Glass may be polished with Putty, Chalk, or Tripoli, sprinkled upon a Cloth: And thus the Operation is compleated. In this Manner are made those shining spherical Glasses (appearing like Glasses filled with Quick-silver) which we sometimes see hung up in Parlours, near the Cieling, to invite the Flies in Summer from the Windows, and other Parts of the Room, where they might prove more offensive.

46. The Operation has considerable Advantages, as being performable in the Cold; and is not attended with Danger from the poisonous Fumes of Arsenic, or other unwholesome Matters, usually employed for this Purpose. And how far it is applicable to the more commodious foiling of the common Looking-Glasses, and other Speculums, may deserve to be considered.

Advantages of the Operation.

EXPERIMENT V.

A curious and useful Glue.

47. We took an Ounce of Ising-Glass beat to shreds, and put it into a Pint of Brandy; where, by Means of a little Heat, or gentle simmering over a common Fire, it gradually dissolved: We then strained the Solution through a Piece of fine Muslin, and thus obtained a Glue,

Ising-Glass Glue.

Glue, that should be kept in a Glass close stopped.

Its Uses.

48. This Glue, with a very gentle Heat, dissolves thin, transparent, and almost limpid: When used in the Manner of common Glue, it joins the Parts of Wood together, stronger than Wood is joined to itself; so that the Pieces thus joined will break in any other Part rather than where they are glued. It is also remarkable, that if Saw-dust, or powdered Wood, be made into a Ball with this Glue, the Ball will prove solid and elastic; so that it may be turned and used as a Bowl, without breaking. And whether, by Means of such a Glue as this, something considerable may not be effected in the embossing of Wood-work, we leave to farther Experience. The Glue being thus made with Brandy, will keep long without corrupting; and is therefore a proper Form wherein to preserve Ising-Glass ready dissolved for the fining of Wines, or other Uses.

Extended.

49. Another curious Use of our Glue is, that it serves excellently for taking off the Impressions of Medals, or Coin: Thus if a little of this melted Glue be poured thinly upon a Guinea, suppose, so as to cover the whole Surface of the Piece, and the Glue be suffered to remain thereon for a Day or two, till it becomes thoroughly dry, it will appear hard and transparent, like a Piece of *Muscovy-Glass*, with the Impression of a fair Guinea in *Entaglio*, as they call it, on one Side, and in *Relievo* on the other.

And improved.

50. This Glue, therefore, dries into a very strong, tough, and transparent Substance; not easily to be hurt or damaged by any Thing but aqueous Moisture, which would soon dissolve it: So that it is not fit to be used in any Work that must be exposed to Wet or Weather. But for a
Glue

Glue to stand the Weather, let choice be made of the common Glue dissolved with Linseed-Oil.

51. The natural and experimental History of *History of* Glue might greatly tend to the Improvement of *Glues* Chemistry. For it should seem as if all animal *wanted.* and vegetable Substances were either originally made of, or might at last be resolved into Glue or Jelly. Doubtless a Knowledge of the Nature of Ropiness, Viscidity, Siziness, Mouldiness, &c. would give considerable Light to Natural Philosophy and Medicine, and lead us farther into the Effects, Nature, and Process of Growth, Fermentation, and Putrefaction. This Enquiry, therefore, should be prosecuted with Care; beginning, for Example, with that viscous Substance the White of the Egg, or Serum of the Blood, in their natural States; and observing how their Tenacity is altered, by moderate Degrees of Warmth or Cold. The Enquiry might next proceed to the mucilaginous Matter of Snails, Frog-Spawn, Fish, and other Animals in Embrio, Vegetables, &c. and gradually descend to Subjects of the mineral Kingdom. And this Enquiry, we apprehend, may be usefully prosecuted without the Assistance of a chemical Apparatus; so as to discover the best Ways of preparing Cements, Glues, Sizes, Jellies, &c. for various mechanical and oeconomical Uses.

EXPERIMENT VI.

Copper made more ductile, and turned of a Gold Colour.

52. Make an Amalgam, of one Part pure Copper, and three Parts clean Quicksilver;
boil

Copper advanced somewhat nearer to Gold.

boil the Amalgam in River-Water for two Hours; then distill off the Quicksilver, and cohobate it once or twice; lastly, fuse the Copper that remains in the Retort, and it will be of a Gold Colour, and more ductile than common Copper. This Experiment was not brought to Perfection in the Course, on Account of the Difficulty then found of amalgamating the Copper, which was attempted thus: We dissolved as much Copper in *Aqua fortis* as the Menstruum would take up; then diluting the Solution with ten or twelve Times its own Weight of Water, we put Iron Plates into it, which precipitated the Copper in fine Powder: This Powder was edulcorated, or washed, in several Waters, to clear it of its adhering Salts, and afterwards dried; then ground in a Stone-Mortar, along with an equal Weight of Quickilver; but no Amalgamation ensued. It has been usually thought difficult, and by some impracticable, to make an Amalgam of Copper by Heat: In which Method, indeed, it is not easy to succeed perfectly, the Copper requiring such a Heat to keep it fluid, as will exhale the Mercury; which besides does not readily unite with that Metal. In the present Method the Thing may be effected without Heat; viz. by first reducing the Copper to an exceeding fine Powder; which here supplies the Place of Fusion, and might put us upon enquiring whether Trituration may not, in some other Cases, be advantageously substituted for Fusion.

Its Use.

53. This uncommon Experiment of M. Homberg shews us a Method of advancing Copper some Degrees nearer to Gold; so as to fit it for Watch-work, Cane-heads, Snuff-boxes, and other smaller Machines and Utensils, and especially for Gilding. It is remarkable that the Quick-

Quicksilver loses an eight Part of its Weight in the Operation.

54. The Experiment is here employed as a *Extended.* leading one, capable of shewing that useful Changes may be wrought upon the common Metals; so as, in some Measure, to introduce a new Set. It is known to some, that Copper may be so far whitened and softened, as to serve on many Occasions for Silver. Lead, by a slight Application, is capable of being whitened, hardened, and rendered more useful for many Purposes. And if Persons acquainted with the Nature and Effects of Metals, Minerals, and their Fumes upon each other, were to prosecute the Enquiry, many useful Things of the like Kind might doubtless be discovered.

55. A little prepared or fixed Arsenic will in- *Exempli-*stantly whiten Copper throughout; though thus *fied.* indeed the Copper proves brittle, or rotten: But there are other secret Ways of whitening it, so as to leave it extreamly ductile.

56. The farther Prosecution of this Subject *The Prose-*would lead us into the sublimer Metallurgy; *cution re-*which is a Part of Chemistry by no Means *commend-*hitherto cultivated as it deserves, seeing it is highly *ed.* capable of enriching the known mechanical Arts, and striking out new ones.

III.

57. We now come to offer a few Rules for *Rules for* conducting chemical Experiments in the Way of *improving* an Art; so as to improve the several Branches *Chemistry* of Chemistry above mentioned *. *and Arts.*

58. Let the first Rule be, with Care and Diligence to observe the Processes used by Nature in

* § 2, &c.

the Production of all those things we would endeavour to imitate. For Nature, the most expert Chemist, employs the very Instruments which Men also employ; viz Fire, Water, Air, and Earth; as we have shewn in our Lectures upon the Elements.

Illustration.

59. To illustrate this Rule by an Example; it appears, by numerous Instances, that there is an acid or saline Liquor naturally contained in the Bowels of the Earth; which acid there mixing with various Kinds of earthy Matters, and acting as a Menstruum upon them, changes their Natures, or makes them appear under different Forms. And hence common Brimstone, Alum, the native Vitriol, &c. seem to have their Origin.

60. For by an exact Scrutiny and attentive Consideration it appears that, when this general Acid dissolves a certain bituminous Earth, it makes Brimstone; when a chalky Earth, Alum; when Iron or Copper, Vitriol; &c. And accordingly, by using the same Kind of general Acid (which may be procured by burning Brimstone under a glass Bell) in the same Manner as Nature seems to employ it, we can likewise, by Art, produce Brimstone, Alum, or Vitriol, when and where we please. And thus, if we could universally discover the Processes and Instruments which Nature employs in the Production of her Effects, we should have certain Rules for imitating her.

Rule II.

61. Our second Rule is, to gain a Habit of transferring, diversifying, enlarging, and improving an Experiment, till it ends in some certain Discovery, either of Light to the Understanding, or of Use in Life; one of which points all just Experiments will end in, when duly prosecuted and considered.

62. For

62. For unsuccessful Experiments are no less instructing than those that succeed: Which ought to be well remarked. The Head must in all Cases co-operate with the Hands: So that the Mind should be ever casting about to discover the Causes of Failure, as well as of Success. And this is a Sagacity which may be procured by Use, and turned into a Habit of Invention and Discovery: So that no single Experiment shall be performed, but some Advantage will be immediately derived from it; nor any Experiment be made, without some reasonable Grounds of Hope for Success. *Illustration.*

63. Our third Rule is, To prosecute Experiments in an orderly Series, with a View to some particular Enquiry that may be of Use in Life; and to let the Enquiry suit the Genius and Temper of the Enquirer, so as that it may be prosecuted by him with Vigour and Pleasure. *Rule III.*

64. Thus, if any one should be averse to the Use of Fire and Furnace, he may still improve Chemistry and Arts, or perform many serviceable chemical Operations, without much Apparatus, or Expence, or without the Utensils and Instruments commonly employed in that Art: Which may, therefore, be practised as well in a Study or Parlour, as in a Laboratory. And to those disposed to operate in this Way, may be recommended the Business of Fermentation, the Concentration of Liquors by Cold, and the Prosecution of the Nature and History of Cold, begun by Mr. Boyle. We might also recommend the extracting of the finer Essences of Vegetables; the making of the more noble and spirituous Infusions, Tinctures, and Elixirs; the examining and tabling the solutive Power of Water with regard to Salts, and of Spirit of Wine with regard *Illustration.*

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regard to different Oils and Rosins; the determining the Force of all known Menstruums in the Cold; the Discovery of new Menstruums, and particularly of a Solvent for the Stone. These, and many other chemical Enquiries, may be prosecuted without the Use of Fires and Furnaces: And even such Tempers as are more delighted with Speculation than Practice, may greatly contribute to the Improvement of Chemistry, by sorting, ranging, and digesting Experiments into Tables; shewing what they prove, and how far they reach; how far they fall short, and how they may be carried farther: Others might employ themselves to Advantage, in drawing Things of Use from the Experiments already known and published: And lastly, others might, from a due Consideration of Experiments, deduce new Directions and Rules of Practice for producing, in a sure and constant Manner, much greater Effects than are usually hoped for.

AXIOMS and CANONS.

1. We learn from the present Lecture, that Chemistry is an Art of very extensive Use in Life; insomuch that not only Natural Philosophy, but also Trades, Commerce, and all active Businesses, have a Dependence upon it, and may be improved by it *.

2. That therefore the Disesteem, which Chemistry has generally met with, proceeds from a Want of knowing its proper Office, Extent, and Usefulness; and from the frequent Misapplica-

* See the whole Lecture *passim*.

tion of it to Things of a delusory or phantastical Nature.

3. That a large Part of general Chemistry may be advantageously practised, and many Discoveries and Improvements made therein, for the Service of Arts, without the direct Use of Chemical Fires, Furnaces, and the common *Apparatus a*).

4. That numerous Discoveries and Improvements remain to be made in Chemistry itself; and that these Improvements may be made in a direct, rational Manner; and, if once made, might greatly enlarge and illustrate Natural Philosophy, improve various Arts, and introduce a Set of new ones *b*).

5. That, in particular, Sal-Ammoniac, an Amber-Varnish, a hard Kind of Glass, a Foil for Glasses, an excellent Glue, and a new Kind of Metal, may be easily obtained, for the Improvement of Pharmacy and Dying, Japanning and Embalming, the Art of Glass and the making of artificial Gems, the Foiling of Glasses, the Gluing of Timber, Embossing, and taking off Impressions, the Art of Watch-making, and for other mechanical Uses.

6. That the Canons for the farther Improvement of Chemistry, and the Arts thereon depending, require, (1) a careful Observation of the Ways of working employed by Nature; (2) a Talent of Experimenting; and (3) the Discretion of suiting the Enquiry to the Temper and Genius of the Enquirer *c*).

a) See § 12, 13. and *Exp.* II. IV. V. and § 63, 64.

b) See the whole Lecture.

c) See § 58—64.

CONCLUSION.

WE are now come to the End of our Lectures, where it may be proper to stop a while, and look back upon the Ground we have gone over. We seem to ourselves to have been travelling in a new Road, too little frequented either by Philosophers, Chemists, or Men of Business. Our Aim has been to improve the useful Arts, by Means of a more Philosophical Chemistry; and at the same Time to shew the Method of conducting Enquiries so as that they may terminate in useful Discoveries. With an Eye fixed upon this Point, we have purposely avoided the more entertaining and agreeable Experiments, wherewith Chemistry abounds; and have kept to such only as were judged either beneficial in themselves, or of Service in discovering Causes, Axioms, and Rules. And if there be any Merit in what we have done, we freely own it to be borrowed, and that it lies in the *Verulamian* Method we have pursued, that is, in endeavouring to rectify the Mind, guard it against Error and Illusion, and conduct it to the Fountains of Nature and Use. We cannot indeed presume to have discovered many of the true Causes of Things, or Axioms perfectly just and universal. To do this, requires that the several Parts of Philosophy should be better cultivated than they are. All we can hope for is, to have found and established a few Rules that may direct to a serviceable Practice, and enable us to enrich and improve some of the present Arts and Sciences. Thus, for Example, we hope to have discovered this philosophical Axiom, That *Sugar, or a saccharine Substance, is the Basis of Wines, Beers, Vinegars, and inflammable*

mable Spirits : Whence we presume, that the Arts of Brewing, Wine-making, Vinegar-making, and Distilling, may receive a great Degree of Perfection. And thus we desire to have it observed, that the Discovery of a single Axiom, or Cause, may often improve, or even perfect, a Number of Arts : For physical Axioms, duly discovered, must be pregnant with the Matter of many Arts and Sciences. And on this Account it is, that we have directed our Enquiries to the Investigation thereof, as the best and surest Means of improving the known Arts, and discovering new ones. Doubtless, if this Method were carefully and generally pursued, the Business of Invention would not long continue to be that casual Thing it now is ; but be reduced to an Art, which, of all others, is, perhaps, the most wanted.

The E N D.

I N D E X.

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